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ORIGINAL ARTICLES.

I.—Relics of the Great Ice Age in the Plains of Northern India.[1]

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IT may seem strange to dwellers in this country under its present conditions to speak of relics of a Glacial Period being visible in the plains of the Ganges Valley, where the mean annual average temperature is about 77° F. and we all know what the maximum may rise to; and at the outset I must guard against misapprehension by saying that I do not mean to imply, by the title of my discourse, that the plains of India were ever, within geologically recent times, covered with snow and ice. We have evidence, it is true, that in long distant ages, at the beginning of the period that saw the filling up of the valleys of the old Gondwana continent, part of which still exists as the Peninsula of India, that is to say, when the deposits of clay and sandstone, supporting a luxuriant vegetation, now transformed into the coal of Raniganj and other localities, were beginning to be laid down, the higher ground of the Peninsula was under snow and ice, and that glaciers descended into the low ground and probably sent off icebergs into the surrounding seas. Traces of these events, which took place in what is known to geologists as the Talchir Period, even the old rock-floors grooved and striated by the passage over them of fragments of rock embedded in moving ice, have been found at the base of the Coal-measures in the Central Provinces and in Rajputana, while a bed containing striated and polished boulders, exhibiting unmistakable evidence of ice action, is known in the Salt Range of the Punjab. But with these, and with traces of what may prove to have been a still older ice age, of which Sir T. Holland brought some evidence before this Society in August, 1908, discovered by him near Simla, I do not propose to deal on the present occasion.

The period of a general lowering of temperature over the northern hemisphere, to which the name of the Glacial Period *par excellence*, or of the "Great Ice Age", has been given, has left abundant traces of its passage over the whole of that hemisphere, wherever the conditions are favourable for the preservation of the peculiar features which denote the action of large bodies of ice. Naturally these features are

[1] A lecture delivered in the rooms of the Asiatic Society of Bengal, Calcutta, on February 10, 1910.

prominent in proportion to the accumulation of ice that took place in any given region. Thus they are clearly visible in all the countries surrounding the Pole, especially so in North America, the British Isles, Scandinavia, and Siberia, where there has been found conclusive evidence to show that, during the period of maximum glaciation, a huge ice-cap buried a very large part of those countries, and in England extended as far south as the Thames Valley. This evidence is rendered more conclusive by the fact that, strictly speaking, the last Glacial Period has not yet come to an end, but that its peculiar characters still persist within the Arctic Circle, and we are therefore able to follow the indications of its passage step by step, from the edge of the great ice-sheet that even now covers the greater part of Greenland and the extreme north of the American continent, southwards across the plains of Canada or the hills of Scotland, until we come upon indubitable signs of what was once the outer edge of the larger ice-sheet of the past.

But the Arctic Circle is not the only region that affords evidence of the persistence into our present humdrum times of the last Glacial Period. Every range of mountains that raises its crest to a sufficient elevation above the sea-level, provided that there is also a sufficient precipitation of moisture, is, as there is no need for me to point out to those of you who have seen the Himalaya, covered with so-called permanent snow and ice, the lower limit of which rises gradually from the sea-level as we recede from the Pole. And in each of these ranges there is equally indubitable evidence, indications of which may be followed down from the still ice-bound crests, through the valleys, of an extension of the ice and snow to much lower altitudes within quite recent times, considered from a geological point of view; so recent that it is quite certain that man, the most highly developed being on the earth, had already appeared and attained to some degree of culture while that period of intense cold was in progress.

It is not my intention to enter now into a discussion of the causes of the Glacial Period, or of the phenomena that marked its passage, except in so far as the latter affect this country. As Sir Archibald Geikie says in his *Text Book of Geology*,[1] "No section of geological history now possesses a more voluminous literature than the Glacial Period," and to give you even the slightest idea of the theories that have been put forward to account for it would lead me far beyond the limits allowable for a single lecture. Even now geologists and other scientific men are not in agreement as to the true cause of this widespread refrigeration of climate, and I must only ask you to accept the assertion that it did take place, though I may say that in case you are not disposed to do so, and prefer to attribute the phenomena I am about to describe to a general inundation, such as Noah's flood, or some similar catastrophe called by another name, you will find yourselves in very good company, even in scientific circles.

In bringing forward evidence which, in my opinion, shows that relics of this Glacial Period are still to be found in the plains of India, it will perhaps be best to follow the same line of inquiry that

[1] 4th ed., vol. p. 1301, note.

I indicated in speaking of the great ice-sheet, and start with those regions where glacial conditions still prevail, the highest ranges of the Himalaya, that is to say, and see what are the peculiar physical features that accompany a lowering of the temperature. The first of these is a former extension of the glaciers far beyond their present limits. As a glacier moves it carries on its surface or embedded in the ice huge accumulations of loose material fallen from the hill-sides rising above it, and at its snout, where the ice melts, deposits this material in an embankment-like heap, known as its terminal moraine, just as a gang of coolies builds up a railway embankment. If then the glacier retreats, this embankment will be left behind as a sign of the former extension of the ice. In many of the Himalayan valleys remains of these ancient moraines have been found as low down as 7000 feet, whereas the present limit of the glaciers varies from 11,000 to 13,000 feet. General McMahon records the existence of an old moraine near Dalhousie, in the North-West Himalaya, at an elevation of about 4740 feet above the sea.[1]

But these ancient moraines are not the only indication that the glaciers were at one time of far greater size. In some cases smoothed and scratched surfaces of rock on the valley sides, far above the present level of the ice, bear witness to its former depth. The striking contrast between the U shape of a valley which has once been occupied by a glacier, and the V shape of the valley below, so characteristic of the inner Himalaya, even where old moraines are absent, affords further proof in the same direction.

But, as I remarked before, we have no evidence that any of these glaciers ever descended as low as the plains of India, though an enthusiastic glaciologist, Mr. Theobald, once a member of the Geological Survey, thought that he had obtained such evidence in Kumaon, in the shape of old moraines, and on the plains of the Potwar, an elevated tract of country lying north of the Salt Range, between the Jhelum and the Indus.[2] We must look for the evidence which I now wish to place before you in another direction.

One of the most striking features of the tracts that lie in the immediate neighbourhood of the snows is the absence of vegetation. Although those who have done no more than make a trip to one of the more accessible glaciers may be charmed by the sight of forests of pines or birches flourishing in close proximity to the ice, and with the grassy sward clothed with flowers that cover even the moraines, a climb of a few thousand feet will bring them to a region where not even a blade of grass is to be found, and the only vegetation met with consists of mosses, lichens, and a few of the most hardy flowering plants. One result of the absence of vegetation is that the agents of disintegration of the rocks have full play. The constant fluctuations of temperature, for even at these altitudes the sun by day has great power, the alternate freezing and melting of water in the pores and interstices of the rocks, the violence of the wind, and the almost constant precipitation of moisture, all combine in

[1] Records, Geol. Surv. Ind., vol. xv, p. 49.

[2] Ibid., vol. vii, p. 86; vol. x, pp. 140, 223; vol. xiii, p. 221. See also A. B. Wynne, ibid., vol. xi, p. 150; vol. xiv, p. 153.

rotting away, if I may so express myself, and breaking up the rocks with great rapidity, in comparison with tracts where the roots of grass and trees hold together and form a protective covering of soil. At these altitudes many of even the highest peaks are almost buried under an accumulation of their own debris, so much so that it is sometimes possible to ascend to heights of 20,000 feet or so with no more discomfort than is caused by the difficulty of breathing in a rarified atmosphere. This loose material is always in a state of more or less unstable equilibrium, and when lying on steep hill-slopes is constantly liable to be precipitated into the valleys, especially when it is saturated with moisture by melting snow or rain. When this happens in a tributary valley, the semi-liquid mass moves irresistibly downwards as an avalanche of mud mingled with boulders and fragments of rock, and on reaching the valley of the main stream or river, spreads itself out as a conical fan, radiating from the mouth of the tributary. In all the valleys of the higher Himalaya these fans can be seen in actual process of formation, and they may sometimes be met with even at elevations well below the snow-line, when the head of the tributary stream reaches up to a sufficiently high altitude. When the side-streams are close together the fans often coalesce, forming a more or less continuous terrace along the banks of the main river.

If we now follow the larger valleys downwards, we find that, when we reach altitudes of say 7000 feet or less, exactly similar cones or fans occur along each bank wherever the main stream is joined by a tributary, but that these fans bear every sign of great antiquity, in proportion to their distance from the snows. Not only are they covered by vegetation and usually cultivated, but they are often selected as sites for villages, on account probably of the ease with which water can be obtained by leading channels from the side-stream. (I have also noticed this propensity in the Alps, where in the main valleys each fan will have its well-watered little town built upon it.) This shows that no fresh material has been spread over the fans within recent times. Moreover, the stream that originally formed them, instead of flowing in devious rivulets over their surface as it did at first, has now cut a single deep channel directly through the centre, so profound in most cases that it is evident that a very long time has elapsed since the stream ceased to construct the fans. Lower down still the whole of the valley is found to be choked with a great thickness, often as much as three or four hundred feet, of loose deposits continuous with and similar to those forming the cones, out of which the river has cut great terraces, now on one side and now on the other, with a perpendicular face towards the river. Sometimes only small remnants of these terraces are now left, but at other times they form large level plateaus, on which considerable towns may be built.

The origin of these terraces has aroused some discussion among geologists, for it is evident that they are now being washed away by the rivers that once deposited them, and that, being high above the present flood-level, there must have been a great change of conditions of some kind since that time. Changes of level, either resulting from

a recent elevation of the mountains or a depression of the plains, causing an increased fall, and consequently higher velocity and greater erosive power in the rivers, have been evoked in order to account for the facts; but a visit to any of the valleys will show that the loose material of the terrace cliffs *extends in most cases down to the present water-level*, and it is evident therefore that the existing valleys *must have been excavated to their present depth* before the terraces were deposited in them. In other words, that the configuration of mountain and valley was much the same before the terrace-forming period as it is now, and that since that period the rivers have been able to do little more than clear out their old channels. There may have been some elevation of the inner Himalaya during the course of these events, but the diminution of the burden thrown into the rivers, due, as we have seen, to the reclothing of the hills with vegetation on the retreat of the ice, is quite sufficient, I think, to account by itself for the change from deposition to erosion. A depression in the Indo-Gangetic Valley, which by increasing the gradient would also increase the erosive power of the rivers, seems equally out of the question; for, as we have seen, the excavation of the river-valleys took place before the terrace-building period, and the material removed from them must have filled up the depression as quickly as it was formed, even if the addition of this weight on the rocky floor below the plains did not actually cause the depression, as some have supposed. In any case, there is nothing to show that during the terrace-building period the hills and plains did not stand in much the same relation to each other as they do now.

Even at the present day it is sometimes possible to find the conditions of the terrace-building reproduced at quite low levels among the hills. Owing to the recent immigration of Nepalese cultivators into Sikkim, the forests that once clothed the hill-sides in that very jungly country have to a great extent been cut down, and the natural consequence is that landslips are very common. One striking instance of this I came across in the valley of the Rangpo, a large tributary of the Teesta north of Kalimpong. The forest on the north bank of this river has been almost entirely cleared off, and owing to the steepness of the hill-slopes and to some peculiarity in the lie of the rocks, an almost continuous line of landslips, extending for several miles, has taken place. These have thrown an enormous quantity of debris into the river, which is unable to carry it away at once, and the bed of the river is thus being rapidly raised, the water flowing in numerous channels over the surface of the deposits. If now the forest were to grow up again and the landslips cease, the supply of material would come to an end, and the river would at once begin to cut for itself a defined channel through the accumulation of loose stuff in its bed, and as it wound from side to side would leave terraces on either bank, and this without our having to imagine any increased velocity in the stream due to increase of gradient.

The terraces I have described are not confined to the valleys of the Himalaya, but are to be found all round the northern limits of the Peninsula, from Assam on the east to Baluchistan on the west. Even in this latter country, now so extremely arid, they attain to

large dimensions, much larger than the puny streams of that country could now account for.

In following down the valleys we have seen that the features peculiar to the upper, still glaciated regions are reproduced at the lower levels, but that the causes that led to the production of these features at these lower levels have now passed away. What is more likely to have been the cause of these similar phenomena than a similarity of conditions, that lowering of temperature and consequent increase in the power of the erosive agencies which we call the Glacial Period; one which we know to have occurred in times geologically recent, but long enough ago to account for the erosion that has since taken place?

It remains now to extend the argument to the plains of India, but it is not to be expected that the evidence in this region will be of so convincing a character as that afforded by the Himalayan valleys. There is some direct evidence, it is true, that the plains participated, as was only natural, in the general refrigeration of climate afforded by the fact that a large number of Himalayan plants are found on the higher hills and plateaus of the Peninsula, and that, as I am informed by Dr. Annandale, of the Indian Museum, a small portion of the fauna of Parasnath Hill in Bengal is of a type peculiar to the Himalaya; showing that the temperature of the intervening plains must have been lowered sufficiently, and that for a long enough period, to allow these plants and animals to wander so far to the south. But this evidence is not of the character that I am dealing with at present. Since the ice and snow did not actually descend to the plains, their influence on the deposits of the latter can only have been of a secondary character, and to a great extent these must have been obliterated by the divagations of the great rivers, so that only the merest relics now remain.

Throughout the valley of the Ganges and its tributaries patches of what is known as the 'older alluvium' are to be found, rising to a considerable height, often as much as 100 feet, above the present flood-levels. This alluvium is generally to be distinguished from the later river-silts by its red colour, which has given the name of Rangamati, 'coloured earth,' to so many villages in Bengal and Assam; and by its containing quantities of the peculiar nodular form of limestone known as 'kunkur', the presence of which is in itself a sign that the deposits are of considerable antiquity, for it owes its origin to the slow accretion of particles of carbonate of lime dissolved out of the slightly calcareous sediments by percolating water, and re-deposited in the form of nodules as the water evaporates.

One of the most conspicuous instances of this old alluvium is the elevated tract known as the Madhupur Jungle, extending to the north of Dacca between the present channel of the Brahmaputra and its old course into the Meghna. The soil of this tract is a stiff red clay, evidently an old river-silt, but raised to a height of some 60 to 100 feet above the flood-levels of the rivers on either side. Several other patches occur in the lower Ganges valley, but as we ascend the river and its tributaries into the United Provinces and Bundelkhand, we find that this older alluvium is almost universally distributed, and has

a distinctive name, that of 'bhangar' in contrast with the low-lying 'khadar' or straths along the river-courses, and that it bears every sign of being in a state of rapid erosion; that it belongs in effect to a condition of things that has now passed away, when the rivers probably possessed a much greater volume of water and brought down correspondingly greater quantities of silt.

Now we have seen that it is possible, indeed quite certain, that during the Glacial Period exceptionally immense quantities of debris were precipitated into the rivers, more indeed than they were able to carry away comfortably, as the terraces in their upper valleys show. Is it not, then, reasonable to suppose that it was then that the lower valleys of the same rivers were choked with a superabundance of silt, and that to this same period it is that we must attribute the formation of the 'older alluvium'; that, in fact, these deposits are as truly relics of the passage of the Glacial Period as the ancient moraines among the hills?

It is always a source of satisfaction to the geologist, or indeed to any scientific man, when he finds that a theory intended to explain a certain series of facts can be used to clear up difficulties that may surround another series of equally well-ascertained facts. The changes of the courses of the rivers of Lower Bengal have for a long time exercised the minds of surveyors, engineers, and geologists, and various explanations of them have been put forward, especially of the comparatively sudden desertion by the Brahmaputra of its old channel, which ran to the east of Dacca at the beginning of the last century. This problem was first seriously attacked by Mr. Fergusson fifty years ago,[1] and partly turns on the question of the origin of the elevated tract of ground I have already mentioned, the Madhupur Jungle. He attributed it to a special upheaval of that part of the delta which deflected the Brahmaputra into the Meghna and the jheels of Sylhet. But we should have to apply the same reasoning to other patches of the older alluvium, and it is difficult to suppose that each of them is due to a special upheaval; moreover, one would think that an upheaval in that particular place would be more likely to force the Brahmaputra westwards than deflect it to the east. Nor does it account for the fact that the Brahmaputra, now a much larger river than the Ganges, allowed itself to be pushed aside in this way; or that, considering that it brings down very much more silt than the Ganges, it should have done so little towards filling up the Sylhet jheels. But a study of the present river-courses will, I think, throw some further light on the subject.

The Dihang, which it is now universally admitted brings down the waters of the Tsanpo of Tibet into the Brahmaputra, is not, I think, the original main channel of the latter, but was, until quite recent times, a mere tributary. It is only within the last thirty years that it has been proved beyond doubt that the Tsanpo is connected with the Brahmaputra, though Rennell was the first to recognize that it must be so in 1765.[2] Only a few days ago I saw a modern atlas in which the

[1] Quart. Journ. Geol. Soc., vol. xix, p. 330.

[2] *Memoir of a Map of Hindoostan*, London, 1792, 2nd ed., p. 356.

Tsanpo was shown as flowing on eastwards into the Salween. Now it is not at all unlikely that, at the period I have been speaking of, the Tsanpo either flowed westwards, as Burrard and Hayden maintain, and escaped through the Himalaya at some other point,[1] or lost itself in the deserts of Tibet, and that then the Dihang *was* a mere tributary of the Brahmaputra, but that it has since cut back at its head into the valley of the Tsanpo and 'beheaded' it. If this was so, the Brahmaputra must have been a comparatively small river at that time, and it is not surprising that in its lower course it was pushed aside by the alluvium brought down by the Ganges and its tributaries. Indeed, it may be that the Madhupur Jungle is a relic of the old delta face of the Ganges, and that to the east of it, at that time, there was open water, reaching perhaps up to the foot of the Khasi Hills; in this way I would account for the backward state of that part of the delta. But when the Dihang beheaded the Tsanpo, and brought down this enormous accession of water, the Brahmaputra began to assert itself. At first it could do little, for the accumulation of alluvium in its path was too great to be swept away, and it had to be content with its old course into the Meghna; but it had a treacherous ally in the Teesta, which had gradually been sapping the defences of the Ganges. The Teesta, wandering from side to side over the old alluvium south of its exit from the hills, swept it away by degrees, wearing down the face of the country to the west of the Madhupur Jungle, and in course of time opened a passage for the spill-water of the Brahmaputra down the Jennai River. Finally the Teesta, frankly deserting its lawful sovereign, the Ganges, threw itself suddenly (this happened so recently as 1787) into the Brahmaputra. The effect of this was not at first noticeable, but it is probable that the extra silt brought down by the Teesta was too much for the Brahmaputra to deal with, hampered as it was already by the damming back of its waters by the Meghna as the latter slowly raised the levels of Sylhet, and that the two allied rivers were compelled to find a new channel. The insignificant Jennai offered the means of escape, and its bed was occupied about one hundred years ago.

The struggle that then began between the Brahmaputra and the Ganges is still in progress, and issue was joined so recently, almost within the memory of men now living, that we cannot suppose that it has yet been fought to a finish, or that developments may not take place that will have far-reaching effects upon the future history of Bengal. The Brahmaputra, being the more powerful river, is not likely to rest content with the advantage it has already gained. Up to the present time, indeed, it has not been able to exert its full strength, for it cannot do so until it has brought the level of the Assam Valley to the state in which it would have been had the valley been originally excavated by a river of the size and power of the present Brahmaputra. As it is, much of the force of the river when in flood is spent in the low ground flanking its course; but when this has been brought to the true 'regimen', there is no doubt but that the river will be able to show its real strength with more

[1] *Geogr. and Geol. of the Himalaya Mountains*, Calcutta, 1907, pt. iii, p. 155.

effect in its lower course. Even in 1838 it had succeeded in damming back the Ganges to such an extent near the confluence that the latter was fordable at several places above Goalundo, and was compelled to seek for a new exit to the sea. The Garai, which leaves the Ganges at Kushtia, was enlarged from a mere creek unable to float a vessel drawing more than a foot or two of water, as Rennell found it in 1764, to a broad and deep river, now the principal steamer-route from Calcutta to the Upper Ganges. What further developments may take place we cannot predict, but it is possible that their influence may be felt still higher up the Ganges, and may even extend to the Jalangi or the Bhagirathi, and so affect the welfare of Calcutta. The mitigation of any evil effects these changes may have is a matter for the consideration of engineers. If they become acute, something might be done to assist the Ganges by inducing the Teesta to return to its old allegiance; but the forces exerted by such vast bodies of moving water are so prodigious that it is unsafe to speculate without a complete knowledge of the facts.

II.—The Geology of the Dolgelley Gold-belt, North Wales.

By Arthur R. Andrew, M.Sc., F.G.S.

(*Continued from April Number*, *p.* 171.)

History and Statistics of Gold-mining in the Dolgelley Area.

IT is believed that the ancient Britons and the Welsh were fully aware of the precious metal which lay among their hills. Three Welsh chieftains are known to have possessed chariots of gold, and it is inferred that this gold was derived from mines which the Welsh worked at an early date. Many gold ornaments have from time to time been unearthed, and as their style differs entirely from that customary at the early Christian period, they are believed to belong to a time long anterior to that of Christianity. Again, it is known that the Romans under Julius Cæsar worked minerals in various parts of Britain, and there are many evidences of Roman mine-workings where gold must have been the principal, if not the sole, object of search. One of the most remarkable of these is outside Merionethshire, at Gogofau, near Pumpsaint, in Carmarthenshire, where the traces of Roman occupancy are undoubted. Another locality, this time in Merionethshire, is reported by Ramsay (12, p. 64) as on the banks of the Allt-y-Wenallt.

Coming nearer to the present, it is well to mention the belief of Readwin (31, p. 1) that gold was worked in Wales during the reign of Charles I. The facts on which Readwin bases his belief are as follows:—Thomas Bushell, between 1631 and 1645, rented royal mines in Merionethshire, near Barmouth; in 1636 he erected a mint at Aberystwyth, ostensibly to coin silver coin; he also coined £3 pieces and other gold pieces; Bushell gave and lent to Charles I some two and a half millions of our money; his was the only mint at the time not under the control of the Parliamentary forces, and thus able to supply the Royalists; Bushell could not have imported the gold into Wales, for he was hemmed in by the Parliamentary

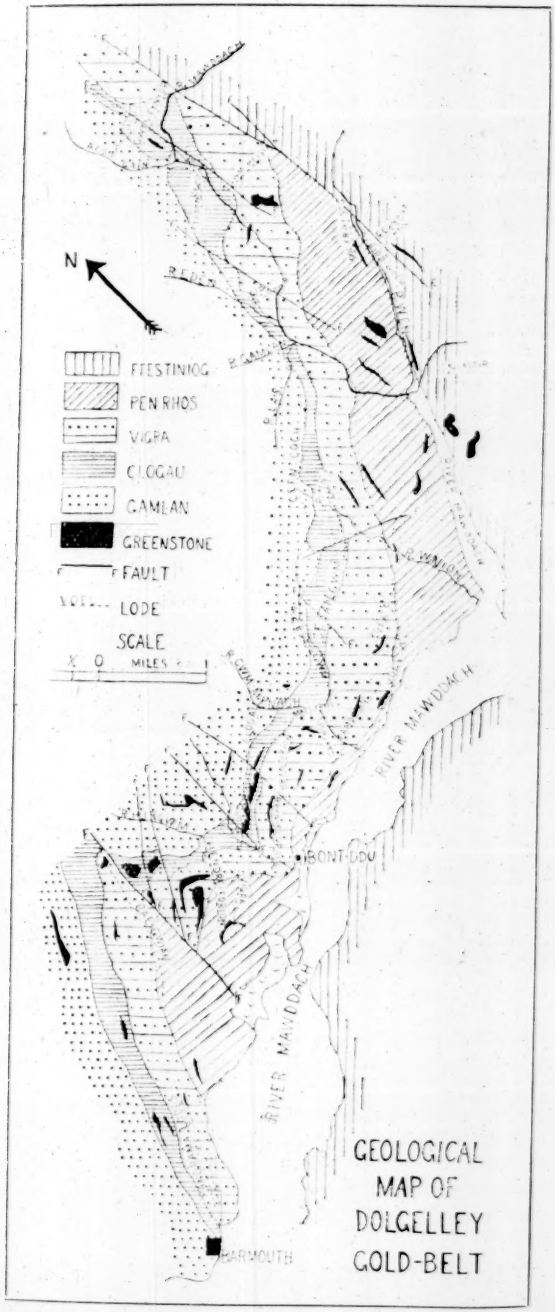
forces. Readwin thinks that Bushell worked the mines chiefly for gold; that he paid Charles one-tenth as royalty, and lent him nearly all the remainder, and that it was not in the interests of either to say anything about it.

At any rate, whether Bushell really worked gold or not, all knowledge of the existence of the precious metal in Merioneth was lost, and it was not until quite recent times that any more was heard of its occurrence. The honour of the discovery or re-discovery was claimed by four persons, of whom Mr. Arthur Dean was, at any rate, the first to publish any definite account; in 1844 he read a paper before the British Association (36) on the existence of gold at Dol-y-frwynog. Mr. Robert Roberts, of Dolgelley, however, claimed that he had discovered gold at Cwm-heisian in 1836 (40); he had had several samples assayed with highly satisfactory results, but believing that any gold-mine was a perquisite of the Crown (gold being a royal metal), he did not prosecute his investigations further till 1843; in the meantime he had informed Mr. Dean that gold and silver did occur in the county (37). Mr. O'Neill is supposed by some to have discovered gold at Cae Mawr in 1836 (40). The fourth claimant to the honour was Mr. James Harvey, proprietor of the mines at Cwm-heisian, who appears in 1836 to have called in Mr. Dean to report on the mines.

The gold-mining industry of the Dolgelley Belt, and of Merionethshire generally, may be said to have commenced in the year 1844. The first effort to raise capital to work the gold-mine was made in 1846, but the idea of profitable gold-mining in Wales only led to ridicule from the investing public. In 1847 the North Wales Silver, Lead, Copper, and Gold Mining Company, with a capital of £125,000, was floated to work the lodes of Vigra, Clogau, Tyddyn-Gwladys, and Dol-y-frwynog; this Company paid most attention to copper, but before 1849 the veins at Cwm-heisian had been thoroughly tested for gold; 300 tons of ore had been milled, and from the resultant $10\frac{3}{4}$ tons of concentrates $7\frac{3}{4}$ pounds of gold had been obtained, worth approximately £350 (41).

Throughout early years the Mines Royal Corporation was a constant obstacle to the progress of the gold-mining industry. This Corporation, by virtue of letters patent granted in Elizabeth's reign, claimed a monopoly of all gold and silver mines in the Principality. After a great amount of litigation a compromise was finally effected, and the Mines Royal Corporation accepted a royalty, which amounted to 5 per cent. of the gross output in the case of private lands and 10 per cent. in the case of Crown lands.

Stimulated no doubt by the gold discoveries of California and Australia, Wales in 1853 experienced a boom of the usual description, gold being reported from any and every part of the country. The mines worked during this period were mostly in the upper reaches of the Afon Mawddach, near to the old mines of Cwm-heisian and Tyddyn-Gwladys. Gold was found at this period in an old dump at the Vigra Mine by Messrs. Parry & Goodman, of Dolgelley (42), and also at the Prince of Wales Mine on the north side of the Mawddach estuary, immediately opposite the Penmaenpool railway station. In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RIVER MAWDACH
BONT-DDU
HARLECH
GEOLOGICAL
MAP OF
DOLGELLEY
GOLD-BELT

1854 Clogau yielded its first gold from a single piece of stone worth £25; in 1856 a hundred pounds of picked quartz from Clogau yielded 14½ ounces of gold (43). In 1860 extensive and valuable finds were made at the St. David's Mine on the Clogau Hill, revealing the extraordinary richness of some of the pockets of this mine; on one day, for instance, 15 cwt. of quartz was mined which yielded between £500 and £600 of gold. In the first half of 1861, 983 ounces of gold, worth £3664, were obtained from the St. David's lode. In 1862 gold was met with in the Berth-lwyd Mine, near Tynygroes. In 1863 gold was discovered at the Ganllwyd, Tyddyn-Gwladys, Glasdir, Moeloffryn, Prince of Wales, Cae-mawr, Cambrian, and Garth-gell Mines, while active operations were in progress at the Cwm-heisian, Dol-y-frwynog, Cefn Coch, and Clogau Mines. The year 1864 witnessed the discovery of gold at the Gwyn-fynydd Mine, and in 1867 the Clogau Mine paid £22,575 in dividends.

Several tables have been published at various times showing the gold production of the Mawddach district from 1844 to 1866; these show considerable discrepancies. I produce here the one which is probably the most correct one; it is derived from official sources (45); the tables which I have omitted are to be found in the works of Phillips (46) and Dr. Ure (40, p. 698).

Gold Production of the Mawddach River District up to 1865.

	Ore.			Gold.		
	Tons.	Cwt.	Qrs.	Oz.	Dwt.	Grs.
Cambrian	50	0	0	30	0	1
Castell-carn-dochan	1132	0	0	888	0	0
Cefn-deuddwr	5	0	0	8	0	0
Clogau (before 1860)	30	0	0	200	0	0
Clogau (after 1860)	4493	15	3	11,493	2	16
Cwm-heisian	300	0	0	184	0	0
Dol-y-frwynog	312	1	2	167	5	5
Gwyn-fynydd	5	1	3	15	15	12
Mawddach River	1	4	0	2	0	0
Prince of Wales (Hafod-y-morfa)	20	0	0	63	0	0
Welsh Gold Mining Company (Cefn Coch)	1602	18	1	585	7	5
Total	7952	1	1	13,636	10	15

From 1866 to 1888 gold-mining in Merionethshire was practically stagnant, the *Vigra and Clogau* and the *Gwyn-fynydd* Mines being worked at intervals, the others not at all. In 1888 rich patches were struck in the Gwyn-fynydd Mine, and this mine has been worked almost continuously since then. For two years it did very well and produced over £38,000 worth of gold; then, encountering a bad year, it was forced to suspend operations, and the Company controlling it was succeeded by another Company which struck rich patches and made handsome profits. Since then the gold return from Merionethshire, practically all from this Dolgelley Gold-belt, has always been considerable, though it has been derived almost entirely from one or

other or both of the two mines, the Vigra and Clogau and the Gwyn-fynydd. J. M. Maclaren, speaking of the years 1900 and 1901 (38, p. 447), said: "The net profits of the St. David's Gold and Copper Mines, Ltd. (the former Vigra and Clogau), for the year 1900 were £39,729, which admitted of the payments of dividends of 60 per cent. on the capital. While the gross receipts for that year were £51,344, the total expenses were only £8423, or 8*s*. 7¾*d*. per ton. The royalties paid to the Crown were £2038, at the rate of 2*s*. 1*d*. per ton of ore crushed." In 1903 the St. David's Gold Mining Company controlled practically all the gold-mines of the district; work was actively pushed forward in the St. David's and Clogau Mine and in the Gwyn-fynydd Mine, and good results were obtained. This Company also did a great amount of development work at the Voel Mine—an amalgamation of the old Prince of Wales, Princess Alice, Moel Ispri, and Cambrian Mines. A large and well-designed mill was erected, principally for saving lead and zinc, but it did very little work.

A table is inserted on p. 206 showing the total production of gold and gold-ore in Merionethshire from 1861 to the present date, and at the same time showing the collective output of the St. David's (Clogau) and the Gwyn-fynydd Mines, the principal mines of the district.

Note.—The table is compiled from that given by J. M. Maclaren, and also from the Mineral Statistics of the United Kingdom for the years 1861 to 1896; from the Inspectors of Mines, Reports, 1880 to 1893; from the Mineral Industry of the United Kingdom, 1894 to 1896; from Mines and Quarries for 1896 to 1907. "Estimated value" of the ore at the mine as furnished to the Mines Department of the Home Office merely means the estimated profit that should accrue from the treatment of the ore, the estimated expenses of the year having been deducted. From 1865 to 1874, and also in 1877, 1883, and 1885, the value (actual) of the gold has been calculated from the weight, taking the value of the gold as £3 17*s*. per ounce. For the years 1905 to 1907 the value has been calculated from that of the total gold output of Wales.

The Lodes of the Dolgelley Gold-belt.

Practically all the auriferous veins of the Dolgelley Gold-belt have been worked to a certain extent; on many, operations have never proceeded beyond the prospecting stage; on others a very considerable amount of work has been done in opening up and developing the ore body. An account will now be given of the various lodes of the belt, commencing in the neighbourhood of Barmouth, and running thence eastward and northward.

Panorama Copper Lodes, Barmouth.—These are situated just above the main road from Barmouth to Dolgelley, and about 2 miles from the former place. There are numerous lodes on the property, of which four are prominent—

1. The gold lode, striking 30° east of north and usually nearly vertical; a few hand-specimens of gold were found here about 1860. In places this lode is well mineralized, chiefly with galena and also

Gold Production of Merionethshire.

Year.	Gold-ore.	Gold.		Estimated Value.	Actual Value.
		Merioneth.	St. David's, etc.		
	Tons.	Ounces.	Ounces.	£	£
1861 . .		2886	2886	—	10,817
1862 . .	804	5299	5299	—	20,391
1863 . .	386	553	527	—	1747
1864 . .	2336	2887	2337	—	9991
1865 . .	4281	1665	542	—	6408
1866 . .	2928	743	214	—	2859
1867 . .	3241	1320	1520	—	5853
1868 . .	1191	436	436	—	1678
1869 . .	—	—	—	—	—
1870 . .	—	191	191	—	735
1871 . .	—	—	—	—	—
1872 . .	—	—	—	—	—
1873 . .	—	—	—	—	—
1874 . .	—	383	383	—	1477
1875 . .	—	548	548	—	2106
1876 . .	—	289	289	—	1119
1877 . .	—	139	139	629	536
1878 . .	—	698	698	—	2825
1879 . .	22	447	447	—	1790
1880 . .	—	5	5	—	19
1881 . .	—	—	—	—	—
1882 . .	—	226	226	—	863
1883 . .	869	66	66	100	254
1884 . .	—	—	—	—	—
1885 . .	35	3	3	7	13
1886 . .	—	—	—	—	—
1887 . .	1	58	58	—	209
1888 . .	3844	8745	8745	27,300	29,982
1889 . .	6226	3890	3864	10,746	13,277
1890 . .	575	206	203	434	675
1891 . .	14,067	4002	4001	12,200	13,700
1892 . .	9990	2835	2835	9168	10,511
1893 . .	4489	2309	2299	7657	8619
1894 . .	6603	4235	4020	13,573	14,811
1895 . .	13,266	6600	6502	16,584	18,528
1896 . .	2765	1353	1208	4257	5033
1897 . .	4517	2032	1738	6282	7185
1898 . .	703	395	241	1158	1299
1899 . .	3047	3327	3203	10,170	12,086
1900 . .	20,802	14,004	13,790	42,925	52,147
1901 . .	16,374	6225	6159	13,920	22,042
1902 . .	29,953	4181	4133	12,621	14,570
1903 . .	28,600	5495	5464	16,995	19,308
1904 . .	23,303	19,653	19,653	68,576	73,925
1905 . .	15,540	5738	5738	17,600	21,006
1906 . .	17,025	1838	1811	5238	6453
1907 . .	12,956	1908	1887	5615	6218
Total .	250,739 (incomplete)	117,913	114,308	303,755 (since 1887)	423,065

with blende and chalcopyrite; the lode may be traced for over half a mile.

2½. The north copper lode, parallel to the above and vertical; it varies in width from 2 inches to 2 feet, and there seems to be no system in its thickening and thinning. Like most of the Welsh gold lodes, its walls are ill-defined; it may be traced at intervals for about 1 mile. The quartz of this lode carries a great deal of chalcopyrite. Besides the weathering products of the copper pyrites, the only other mineral present is pyrrhotite, and that in small quantity only. There is a north and south lode, which intersects this lode, and to the west of the junction the main lode becomes much thinner, but much richer in copper.

3. The middle lode is south of the previous one; it strikes 40° east of north, is again practically vertical, and may be traced for half a mile. This lode is opened up at two levels: in the upper, good copper ore is found in the neighbourhood of a north and south cross-course; in the lower level (180 feet below) the lode is poorly defined and carries no copper values.

4. The north-and-south lode, which is not worked, is poorly mineralized; there is only a very small amount of galena, blende, and chalcopyrite. The lode is of importance only on account of the effect it appears to have on the copper values in the north copper lode. It dips strongly towards the west at an angle of about 45°.

All these lodes are found in the Vigra Beds of the Maentwrog.

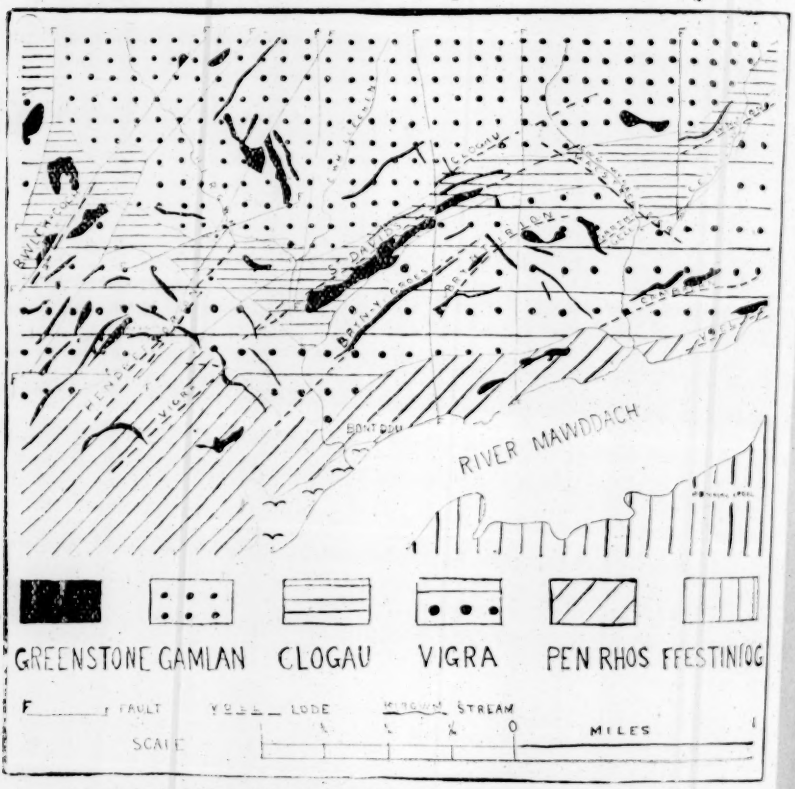
Cae-Gwian Lode.—This is a poorly defined and little developed lode, about 2 miles up the stream which flows into the estuary at Pont Glandwr. The strike of the lode is about 30° east of north, and the dip is 80° towards the west; it may be roughly traced for 1½ miles; the width is irregular, averaging about 1 foot. Copper pyrites and iron pyrites, with oxides of iron and manganese, are seen in the outcrops, and are present in very small quantity only. The southern end of the lode is seen in the Pen Rhos Beds; going north, the lode enters and crosses the Vigra, and finally in the Clogau Beds comes to a termination against the Llynbodlyn fault.

Farchynys Lodes.—On the edge of the estuary immediately south of Farchynys House, there are several outcrops of quartz belonging to three sets of vertical veins, striking 40° east of north; these can be traced only a short distance. The lodes are on the average about 2 feet wide, and are poorly mineralized. A small amount of mining work has been done and gold obtained, assays conducted by Readwin giving 6 dwt. of gold per ton. This lode lies well up in the Pen Rhos Beds of the Maentwrog.

Bwlch-coch-uchaf Lode.—To the east of the Cae-gwian lode, and on the east side of the Llynbodlyn fault, there is a parallel lode striking 30° east of north; it is only traceable for a distance of 500 yards; its width is about 1 foot on the average; copper pyrites and iron pyrites are seen in the lode. The lode cuts through the Vigra Beds and skirts the edge of a sill of greenstone.

Hafod-uchaf Copper Lode.—This is probably a continuation of the Bwlch-coch-uchaf lode, though no trace of a lode formation can be seen in the partially drift-coloured 1000 yards which intervene. The

strike at Hafod-uchaf is 35° east of north, and the dip is in general towards the west at an angle of 80°. The lode branches frequently, the separated parts usually dying out in a very short distance. This Hafod-uchaf lode exhibits in many parts a banded structure due to the alternation and admixture of green shale and quartz. The lode is sometimes 7 or 8 feet in width, its average width, however, being about 3 or 3½ feet; the walls are fairly well defined. The prevailing minerals in the lode are quartz, chalcopyrite, and pyrites; no gold has been taken from this lode. In places the lode is very well



Geological Map of the St. David's section of the Dolgelley Gold-belt.

mineralized, but the average tenor of the ore is so much impoverished by long stretches of barren quartz that the lode has not paid working expenses. This lode cuts through the Gamlan Shales, and is intimately associated with an intrusion of greenstone which it intersects at several places.

Hendre-forion Lode.—Half a mile to the east of the Hafod-uchaf lode, i.e. a little to the north of the Hendre-forion Farm in the Hirgwm Valley, there is another parallel lode striking 30° east of north, which can be traced for half a mile; the dip is slightly towards

the west. The lode ranges up to 6 feet in width, averaging about 1½ feet throughout its traceable length. The quartz is poorly mineralized, containing occasional pyrites only. The lode occurs in the Gamlan Shales, and runs along and across numerous greenstone intrusions; it occupies a fault plane which can be traced for several miles north and south.

West Vigra or Nant-goch Lode.—On the west side of the Vigra Mountain there are several abandoned copper workings close to the Nant-goch Farm. The lode worked can be traced for about 1½ miles over the shoulder of Y Vigra to the Hirgwm stream, and perhaps for half a mile beyond, its strike being 35° east of north. The part on the west flanks of Y Vigra used to be called the Nant-goch lode; that on the north flanks the West Vigra lode. The lode is vertical; in width it varies from a few inches up to 20 feet. Besides quartz the lode contains abundant chalcopyrite, pyrites, and pyrrhotite, with a little galena; the latter becomes the most common mineral where the lode crosses the shoulder of the Vigra spur. Assays of this lode in 1861 by Readwin (34) gave 13 grains of gold per ton. In the south the lode traverses the Pen Rhos Slates; towards the north it traverses the Vigra and Clogau Beds, and finally dies out in the Gamlan Shales. The lode as a rule runs along the junction of the sedimentary rocks and the many greenstone intrusions which occur along its course.

Vigra Lodes.—The Vigra Mine worked on two intersecting quartz lodes, which formed a conspicuous outcrop of white quartz high on the flanks of Y Vigra. One of the lodes strikes almost due east and west, dipping to the south at an angle of 70°. It can be traced for a distance of 300 yards only to the west of the workings, and here it has been worked to some considerable extent. In width it varies from 4 to 6 feet; the lode material is of clear white quartz, carrying in places chalcopyrite. The second of the lodes is more important; at the Vigra Mine its strike is 60° east of north, dipping 75° to the north; to the west it can be traced for a distance of 1000 yards; to the east it can be traced into the continuation of the St. David's lode. At the Vigra workings this principal lode system consists of two parallel veins about 30 yards apart, connected with each other by a series of leaders and cross-veins. Both these veins are irregular in width, swelling out to 6 feet and then pinching in to a few inches. A low-level cross-cut was driven to intersect the lode at a depth of about 400 feet below the upper workings, but was not successful in picking up the lode at that depth. The lode matter is quartz impregnated with copper pyrites; enclosed in the lode are blocks of black shale impregnated with chalcopyrite, bornite, erubescite, arsenopyrite, and to a small extent gold; in some parts the lode contains rhodonite; the mine waters are acid and carry copper in solution. At the Vigra workings where the lode is best developed, it crosses the Vigra Beds of the Maentwrog; to the west it crosses the Pen Rhos Beds, while to the east it enters the Clogau Beds. Where the lode is most prominent it is accompanied by intrusive greenstones.

Clogau and St. David's Lode.—This and the Gwyn-fynydd lode, which will be mentioned later, are the principal lodes of the Dolgelley Gold-belt. The easterly continuation of the main Vigra lode, known

as the Clogau and St. David's lode, runs up over the shoulder of the Clogau Hill and down the other side to the Afon Cwm-Mynach. Near the top of the hill it is cut across by the north and south Bryntirion fault, which moves the eastern end 100 yards to the north. This eastern end has been known as the St. David's lode, the western end as the Clogau. After it passes over the Clogau Hill the lode becomes thinner and poorer, and little work has been done on it. The lode continues, however, as the Cae-mab-seifion lode. On the slopes of Clogau the lode has been worked for a distance of about 1 mile; the combined outcrops of the continuous Vigra, Clogau, St. David's, and Cae-mab-seifion lodes may be traced for about 3½ miles, the longest known line of outcrop in the Dolgelley Gold-belt.

The strike of the Clogau lode is 35° east of north, the dip being vertical with slight oscillations to either side. For a great distance the lode lies among the Clogau black slates, to which it runs parallel in strike though not in dip; throughout its whole length in the Clogau Beds it is intimately associated with the Llech-fraith greenstone sill. The walls of the lode very often show slickensides, and are in most places separated from the vein-stuff by more or less distinct clayey selvages. To the north-east the lode leaves the Clogau Beds and traverses the Gamlan Shales, where it is associated with very few greenstones.

The lode, or rather lode system, branches into parallel veins connected by cross-veins and stringers; thus there are three lodes in the St. David's Mine—the north, the main, and the south; to the south-west they unite to form one lode with frequent stringers and offshoots. These individual lodes vary greatly in width, ranging from 20 feet down to streaks, inches only in thickness.

Fragments of the wall rock frequently appear in the vein-stuff of the lodes, and these black, often talcose fragments of shale may at times give a brecciated appearance to the vein. The vein often has a banded structure, due to stringers or bands of slate or greenstone, separated from each other by bands of white quartz; drusy cavities are common. In addition to the white quartz and calcite which carries little besides pyrites and pyrrhotite, there is also a dark quartz, discoloured by inclusions of minerals and particles of the country rock. Pyrites, pyrrhotite, chalcopyrite, galena, blende, arsenopyrite, tetradymite, and gold occur, chiefly in the darker quartz; of these, gold and chalcopyrite are the only ones that occur in abundance.

During the years of which full returns have been published (1861–1907), these lodes have returned 77,501 ounces of gold from 145,080 tons of quartz. Analyses of gold from the Clogau lodes gave the following results (27):—

	Gold.	*Silver.*	*Quartz.*	*Iron.*	*Copper.*	*Loss.*	*Total.*	*S.G.*
(1)	90·16	9·26	·32	trace	trace	·26	100·00	17·26
(2)	89·83	9·24	·74	trace	—	·19	100·00	15·62

The gold is very variable in its distribution, the rich patches being found in a most unevenly scattered system of pockets. Some of the pockets are very rich; in one case 130 ounces of mixed quartz and gold, broken from the lode, were melted down direct, giving 116 ounces of retorted gold. The pockets are, as a rule, found in the bands of

dark bluish quartz, not in the white quartz. They are frequently associated with the included fragments of the Clogau Slates; and crystals of gold, along with other minerals, may be seen adhering to the slaty surface. The occurrence of tetradymite is regarded by the miners as a favourable indication for gold.

It is certain that the wall rock has some effect on the distribution of the gold, for so far not a single pocket has been found where the lode has entered into the Gamlan Shales.

In the grits and greywackes of the Barmouth Series, immediately to the north of the lode, many fractures or cross-courses may be seen, which run straight towards the lode and intersect it. It is most probable, indeed, that these fractures are responsible, in part at any rate, for the distribution of the pockets, as they afford an easy channel for the passage of mineral solutions containing gold or some precipitant of gold. In many cases, the shoots of gold run more or less transversely across the lode; a system of cross-courses certainly favours such a distribution. In 1875 (40, p. 695) it was noticed that the lode was very rich behind one of these cross-courses. The possible importance of these cross-courses on the distribution of the pockets in the mine has not, however, been recognized, as no systematic attempt seems to have been made to follow the cross-courses in the search for the rich pockets.

(*To be continued in our next Number.*)

III.—Sedgwick Museum Notes.

New Fossils from the Dufton Shales.

By F. R. Cowper Reed, M.A., F.G.S.

Part I.

(PLATE XVI.)

A SMALL collection of fossils was made a few years ago by Mr. V. M. Turnbull from a cutting on the Alston Road, near Melmerby, and the author[1] has already described a new species of *Lichas* (*L. melmerbiensis*) which was included amongst them. Several more new species of trilobites and other groups are now described, and the complete list of the fauna is as follows[2]:—

Trilobita.

Phacops apiculatus, Salt.*
Calymene senaria (Salt., non auctt.).
C. Caractaci, Salt.
Trinucleus Nicholsoni, sp. nov.*
Acidaspis semicevolata, sp. nov.
Lichas melmerbiensis, Reed.*
Turquistia Nicholsoni, Reed.
Homalonotus bisulcatus, Salt. (?).
Homalonotus cf. *Edgelli*, Salt.
H. ascriptus, sp. nov.
Illaenus Bowmani, Salt. (?).

Ostracoda.

Beyrichia (*Tetradella*) *Turnbulli*, sp. nov.
B. (*Ctenobolbina?*) *superciliata*, sp. nov.
B. (*Ceratopsis*) *duftonensis*, sp. nov.*
Turrilepas sp.

Mollusca.

Cyrtolites aff. *ornatus*, Conr.
Bellerophon (*Sinuites*) sp.
B. (*Oxydiscus*) *acutus*, Sow. (?).
Cyclonema aff. *crebristria*, McCoy.
Holopea sp.

[1] Reed, Geol. Mag., 1907, Dec. V, Vol. IV, pp. 396–400, Pl. XVII.

[2] For other lists of fossils from the Dufton Shales, see Harkness, Q.J.G.S., 1865, vol. xxi, p. 248; Harkness & Nicholson, ibid., 1877, vol. xxxiii, pp. 462–3; Marr & Nicholson, ibid., 1891, vol. xlvii, pp. 505, 511.

Pleurotomaria (?) sp.
Trochonema sp.
Tentaculites sp.
Conularia aff. *plicata*, Slater.
Ctenodonta (?) sp.
Pterinea (?) sp.

Bryozoa.

Crisinella Wimani, sp. nov.
Monotrypa (?) sp.

Brachiopoda.

Lingula tenuigranulata, McCoy.*
Lingula sp.
Orbiculoidea perrugata, McCoy.
O. oblongata, Portl.*
Acrotreta Nicholsoni, Dav. (?).
Siphonotreta scotica, Dav. (?).
Orthis juguis, Sow.*
O. testudinaria, Dalm.*
O. Actoniæ, Sow.
O. duftonensis, sp. nov.
O. melmerbiensis, sp. nov.
O. turgida, McCoy (?).
O. (*Scenidium*?) *equivocalis*, sp. nov.
Strophomena (?) sp.*
Leptæna rhomboidalis (Wilck.).

Incertæ sedis.

Pasceolus sp.

Crinoidea.

Stem joints (round and pentagonal).

The species marked thus * are most abundant.

TRILOBITA.

Trinucleus Nicholsoni, sp. nov. Pl. XVI, Figs. 1–9.

Head-shield rather more than a semicircle, widest across middle, somewhat contracted at base; posterior margin inclined to lateral margin on each side at 75°–80°; fringe sloping downwards but not steeply inclined, slightly produced backwards at genal angles which are furnished with long spines. Glabella pyriform, much elevated and swollen, most so anteriorly, gradually decreasing in width and height posteriorly to occipital ring without forming neck; front end projects slightly beyond cheeks to fringe or overhangs the inner row of pits; small median tubercle present on surface of glabella, and on each side near its base are two pairs of small deep pits in axial furrows, the posterior pair in occipital furrow. Occipital ring narrow, nearly as elevated as glabella, separated off by shallow furrow, and furnished posteriorly with a short stout spine directed backwards and upwards at an angle to the general plane of head-shield and about one-third the length of the glabella. Cheeks forming spherical triangles, longer than wide, less swollen and elevated than glabella, highest along axial furrows, with posterior outer angle rounded, and minute granulation over whole surface. Fringe inclined, sloping downwards and widening to genal angles which are provided with long tapering genal spines curving first slightly inwards and then outwards. In anterior part of fringe are four rows of equal-sized pits arranged regularly in concentric and radial rows; the pits in outermost row are sometimes rather smaller. On the lower surface of the fringe the two outermost concentric rows are separated from the inner ones by a strong concentric ridge continued back to the genal angles and longitudinally along the spines. In front of and at the side of the cheeks the fringe widens slightly, and inside the four regular rows are introduced one or two shorter concentric rows of smaller pits with less distinct radial arrangement, so that 5–6 rows with a few smaller irregularly developed pits can be detected at the posterior outer angles of cheeks rounding them off. In some specimens the pits near the genal angles tend to be alternate. The true genal angle (i.e. the base of the spines where the pitted fringe ends) is level

with the second or third thoracic segment, and the posterior and lateral edges of the head-shield meet here at about 75°–80°. Neck-segment behind cheeks narrow, rounded, marked off by distinct but weak furrow. Surface of fringe coarsely granulated.

Thoracic axis about one-sixth the width of thorax, narrow, prominent, cylindrical, with pair of deep pits in furrows between the rings inside and above axial furrows. Pleuræ of usual type, narrow, horizontally extended, flat, with strong diagonal furrow running to obliquely truncate tip. Inner edge of backwardly produced genal angles of fringe overlaps ends of first three pleuræ.

Pygidium broadly triangular; axis long, narrow, conical, reaching posterior edge, less than one-fifth width of pygidium, composed of 9–10 rings, of which the first 3–5 are distinct and well separated by transverse furrows deepest at sides. Lateral lobes flat, horizontal, with traces of 4–6 radiating fine grooves on each side separating the flat pleuræ and corresponding to axial rings. Margin of pygidium bevelled, steeply inclined.

		mm.
Dimensions.	Length of head-shield (without spine) . .	10–15
	Width of head-shield	20–25

Remarks.—The characters and shape of the glabella separate this species from *T. seticornis*, for it is not divided into a swollen frontal lobe and depressed cylindrical neck, though the more or less inclined fringe and position of the concentric ridge on its lower surface and median tubercle on the glabella are features in common. *T. Bucklandi*, Barr., as represented in the Girvan district,[1] has the glabella differing in the same way, and the genal angles are much more produced backwards. The shape of the glabella and presence of nuchal spine are much like *T. Bureaui*, Oehlert,[2] but otherwise the head-shield is distinct. In *T. concentricus*, Eaton,[3] it is the glabella, not the occipital ring, which is produced backwards into a spine; only the outermost row of pits on the fringe is separated off by the concentric ridge on the lower surface, and there are no lateral slits or pits near the base of the glabella; the radial arrangement of the pits on the fringe is not as a rule so well marked in any of the American specimens which I have examined, and there is no median tubercle on the glabella, though its general shape is very similar. The British forms referred by various authors to *T. concentricus* vary so greatly that probably more than one species, or at any rate several distinct varieties, have been included. Amongst the varieties recognized by Salter, *T. farus*[4] bears some resemblance to *T. Nicholsoni* in the shape of the glabella with pits at its base and in the presence of a nuchal spine, but the fringe has different characters. *T. fimbriatus*, Murch.,[5] does not seem to be closely allied.

We may draw particular attention to the resemblance of this

[1] Reed, *Girvan Trilobites* (Palæont. Soc.), 1903, pt. i, p. 10, pl. i, figs. 10–14.
[2] Oehlert, Bull. Soc. Géol. France, 1895, vol. xxiii, p. 300, pl. i.
[3] Hall, *Palæont. N.Y.*, 1847, vol. i, pp. 249, 255, pl. lxv, figs. 4*a–c*; pl. lxvii, figs. 1*a–h*.
[4] Salter, Mem. Geol. Surv., vol. ii, pt. i, pl. ix, fig. 5; id., Dec. Geol. Surv., 1853, vol. vii, pl. vii, p. 6.
[5] McCoy, *Brit. Palæoz. Foss.*, 1851, p. 146, pl. i E, fig. 16.

species to some of the so-called varieties of *T. concentricus* from Tyrone which Portlock described as distinct species. The form ascribed by B. Smith [1] to Portlock's *T. elongatus*,[2] under the designation of *T. concentricus* var. *elongatus*, has a nuchal spine similar to *T. Nicholsoni* and more elongated cheeks and glabella than in the true *T. concentricus*; apparently there is a median tubercle present, and there is mention made of "incipient furrows" at the base of the glabella which correspond to the pits in the axial furrows described in the Dufton species. But the pits in the fringe at the genal angles are more numerous in the Tyrone examples. In the form termed *T. concentricus* var. *Portlocki* by Smith,[3] it is remarked that the three rows of pits in front of the glabella tend to become confluent in a radial direction, as rarely in *T. Nicholsoni*. The Shropshire specimens referred to *T. concentricus* have the pits of the concentric rows arranged alternately, so that the radial arrangement is lost (as in examples of this species from Cincinnati), whereas in many of the Welsh specimens there is a radial regularity observable. Barrande's *T. ornatus* (Sternb.) [4] seems closely allied to our Dufton species in the shape of the head-shield, nuchal spine, pits in axial furrows, tubercle on glabella, and radial arrangement of the pits on the fringe; but these pits are more numerous and smaller. Further investigation will, it is believed, establish the specific independence of several British forms.

EXPLANATION OF PLATE XVI.

TRINUCLEUS NICHOLSONI, sp. nov.

FIG. 1. Head-shield, with portion of thorax attached, showing impression of lower surface of fringe with concentric ridge and genal spines. × 2.
,, 2. Head-shield, showing ditto. × 2.
,, 3. Head-shield, showing upper surface of fringe, etc. × 2½.
,, 3*a*. Portion of fringe. × 10.
,, 4. Head-shield. × 3.
,, 5. Ditto. × 2½.
,, 6. Impression of upper surface of fringe and cheek. × 2½.
,, 7. Nearly complete head-shield. × 2½.
,, 7*a*. Side-view of same, showing nuchal spine. × 2½.
,, 8. Head-shield, showing impression of lower surface of fringe. × 2½.
,, 8*a*. Side-view of same, showing impression of concentric ridge. × 2½.
,, 9. Pygidium. × 2.

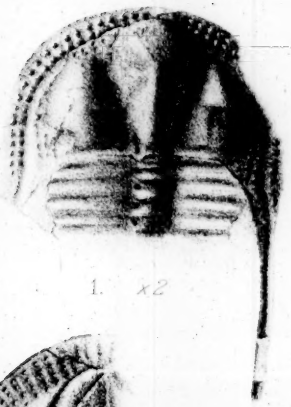
Part II.

(PLATE XVII.)

ACIDASPIS SEMIEVOLUTA, sp. nov. Pl. XVII, Figs. 1–3.

Head-shield semicircular, with middle part projecting behind base of cheeks. Glabella moderately convex, oval, widest across middle, well defined by strong continuous curved axial furrows; lateral lobes

[1] B. Smith, Proc. Roy. Irish Acad., 1907, vol. xxvi, sect. B, No. 9, p. 122, pl. viii, figs. 3, 4.
[2] Portlock, *Geol. Rep. Londond.*, p. 263, pl. i B, fig. 7.
[3] B. Smith, op. cit., p. 121, pl. viii, figs. 1, 2.
[4] Barrande, Syst. Silur. Bohême, vol. i, p. 623, pl. xxix, figs. 1–9; pl. xxv, figs. 41–60.



1. ×2

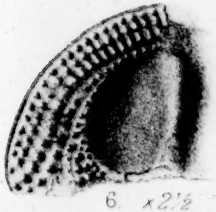
2. ×2

3. ×2½

3a. ×10

4. ×3

5. ×2½



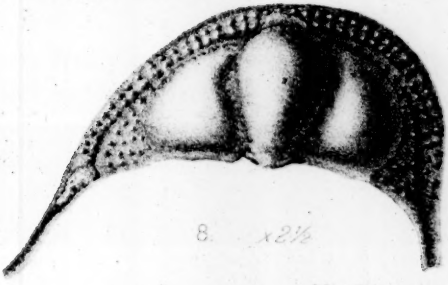
6. ×2½

7. ×2½

9. ×2

7a. ×2½

8a. ×2½



8. ×2½

A. H. Searle del. et lith. West, Newman imp.

Trinucleus from Dufton Shales.

completely circumscribed, except first pair. Basal lobes large, oval, swollen, half the length and one-third the width of the glabella, and placed parallel to its longitudinal axis. Middle lateral lobes sub-circular, invading sides of axial lobe of glabella. Anterior lateral lobes very small, imperfectly separated from anterior lateral angles of axial lobe. Axial lobe of glabella sub-cylindrical, rather more than one-third the width of glabella at base, expanding again between basal and middle lateral lobes and again in front, with anterior lateral angles small and overhanging anterior lateral lobes; anterior end of glabella sub-truncate.

Fixed cheek narrow, curved, convex, rounded, increasing slightly in width posteriorly, embracing side of glabella back to eye, where it has about one-fifth the basal width of the glabella; behind eye descends steeply to narrow neck-ring; posterior lateral wing of fixed cheek somewhat flattened, extending horizontally outwards to facial suture. Ocular ridge forming very narrow rounded band outside fixed cheek, running back to eye. Eyes small, situated very far back, lying behind the middle of basal lobes of glabella, and at about two-thirds their width from axial furrows. Facial sutures curving steeply backward to eyes, running almost parallel to axial furrows; behind eyes bending out very sharply (nearly at right angles to anterior branch) to follow a course nearly parallel to posterior margin of head-shield before curving back to cut this margin at a distance from the axial furrows nearly equal to width of glabella.

Occipital segment forming broad flattened band projecting behind cheeks, and having a width equal to nearly one-third the length of the glabella, narrowing laterally behind basal lobes where it rises into a pair of small oval nodules. Occipital furrow strong, straight. Neck-segment very narrow. Free-cheek triangular, convex, sloping down from eye to concave marginal part, with strong raised narrow angulated border, bearing about twelve equidistant recurved short spines, successively increasing in length towards genal angle. Whole surface of head-shield tuberculated.

Pygidium (imperfectly known), broadly semicircular, with strongly convex prominent short sub-cylindrical axis, one-third the width of pygidium and not reaching posterior margin, composed of two distinct rings (with traces of a third) of which the first is by far the most prominent, and is ornamented with a single row of tubercles. Margin of pygidium armed with five pairs of spines, of which the first two pairs are small, short, slender, sub-equal, and directed radially outwards (these are somewhat indistinct and uncertain); third pair stouter and longer than the rest, nearly as long as pygidium, slightly divergent and connected as curved ridges across lateral lobes with first axial ring; two posterior and inner pairs of spines sub-parallel, slender, sub-equal, and directed backwards.

		mm.
Dimensions.	Length of head-shield	8·0
	Width of glabella	6·0
	Length of glabella	5·5
	Length of pygidium (without spines) . .	3·0

Remarks.—Two good head-shields, one free-cheek, and a somewhat

imperfect pygidium form the material available. The head-shield much resembles that of the species termed *A. evoluta*, by Törnquist,[1] from the *Leptæna* limestone, but the pygidium of this form is unknown. A new species (undescribed) from the Starfish Bed, Girvan, also possesses many points of similarity, both in the head and pygidium. The free-cheek is somewhat like that of *A. callipareos*, Wyv. Thomson.[2]

HOMALONOTUS ASCRIPTUS, sp. nov. Pl. XVII, Figs. 4–8.

There is an imperfectly known species of *Homalonotus* occurring in the Dufton Shales which differs in certain particulars from *H. bisulcatus*, to which it is allied, and may be separated as a new species under the name *ascriptus*. The glabella is narrower, longer, and more cylindrical, the sides are nearly straight and the anterior end is more abruptly truncated, resembling in these respects that of the small head-shield from Horderley, figured by Salter (Mon. Brit. Trilob., pl. x, fig. 10), which he considered might possibly belong to *H. Edgelli*, a species founded on a pygidium. Close to the base of the glabella the axial furrows, which are deep, straight, and not sinuous (as they are in *H. bisulcatus*), diverge a little. The cheeks are narrower, more elevated and swollen, especially in the young individuals (Figs. 6, 7), than in the last-named species, particularly near the eyes, which are placed rather further forward. The pre-glabellar portion of the head-shield is narrower, being only about one-fourth the length of the head-shield, and is flattened and bent upwards, while the anterior margin of it is straight. The occipital segment and furrow seem developed as in *H. bisulcatus*. The anterior branches of the facial sutures run back to the eyes almost parallel, and the posterior branches curve out strongly in the usual way from the eyes, bending back finally to cut the posterior margin at a distance from the axial furrows about equal to the whole basal width of the glabella. The free-cheeks are unknown. A remarkable feature is that on the larger specimens the whole surface of the head-shield is covered with closely set small tubercles, which near the anterior lateral angles of the glabella are developed on the cheeks into minute erect sharp spinules, and this character alone would seem sufficient to separate this species from *H. bisulcatus*.

In the smaller specimens referred somewhat doubtfully to this species the surface of the shell is not preserved, but the eyes and cheeks are more perfect (Figs. 6, 7).

A small hypostome (Fig. 8) about 3 mm. long, of a sub-quadrate shape, may belong to this species; it is nearly parallel-sided and as wide as long; the body is rounded, weakly convex, clearly marked off from the border, has a pair of long lateral furrows running obliquely back from the anterior corners at a small angle to the sides for about three-fourths its length; the border is rounded and somewhat swollen at the sides with small obtuse anterior wings; the posterior border is wider, marked off by a strong furrow deepened at the ends.

[1] Törnquist, Siljans. Trilobitf. (Sver. Geol. Undersokn., 1884), ser. c, No. 66, p. 28, t. i, fig. 54.

[2] Reed, *Girvan Trilobites*, 1904, vol. ii, p. 112, pl. xv, figs. 11, 13.

		I. mm.	II. mm.
Dimensions.	Length of head-shield . .	16·5	*c.* 8·0
	Length of glabella + occipital ring	13·5	7·5
	Width of glabella at base . .	9·5	5·0
	Width of glabella at front end .	7·0	4·0
	Width of head-shield between eyes	14·0	8 0
	Width of head-shield at base .	—	16·0

OSTRACODA.

BEYRICHIA (CERATOPSIS) DUFTONENSIS, sp. nov. Pl. XVII, Figs. 9–11*a*.

Carapace semi-ellipitical, slightly oblique, rather elongate, widening a little posteriorly; anterior end somewhat pointed; posterior end wider and obliquely truncate above or rounded. Hinge-line straight, as long as carapace. Valves moderately convex, crossed by three swollen rounded lobes united below by sharp narrow sub-marginal ridge elevated into a thin rib on its crest running along middle of anterior lobe, then concentrically with ventral margin, then up posterior lobe, bending obliquely forward to ascend to summit of the upstanding process of this lobe. Anterior lobe with a width about one-third the length of valve, narrowing slightly below, more or less swollen and rounded; first sulcus rather obliquely inclined backwards, traversing three-fourths the width of the shell; middle lobe narrow, prominent, straight, vertical, nearly reaching marginal furrow below; second sulcus straighter and more vertical than first sulcus; accessory lobe represented by small node or tubercle almost isolated, situated about half-way down posterior lobe and separated from it by strong oblique sulcus, which is continued backwards to about middle of posterior margin, expanding somewhat and dividing the posterior lobe into two unequal parts, of which the lower forms a small elongated elliptical lobe, obliquely directed upwards and forwards with the accessory lobe at its upper end; the upper portion of the posterior lobe is strongly elevated, rising nearly at right angles to valve, and projecting a little above hinge-line as a blunt sub-conical process with flattened posterior face, and with its lower edge sharpened by the continuation of the sub-marginal crest, and beaded or fimbriated. Border flattened, set at right angles to plane of valves, with median narrow raised rim ornamented with a row of closely placed small tubercles. Surface of valves smooth.

		mm.
Dimensions.	Length . .	2·75–3·0
	Width . .	1·75–2·0

Remarks.—The relations of this species are wide. The raised process on the posterior lobe closely resembles that of *B.* (*Cer.*) *oculifera*, Hall,[1] but the border of the valves is different. The crest on the lobes recalls the sub-genus *Steusloffia*,[2] and similar crests are present in *Strepula*,[3] but they have no genetic significance. With *B.* (*Cer.*) *Chambersi*, Miller,[4] our species agrees in the reduction or

[1] Jones, Q.J.G.S., 1890, vol. xlvi, p. 21, pl. iv, figs. 19, 20; Ulrich, Proc. U.S. Nat. Mus., 1908, vol. xxxv, p. 308, pl. xxxix, figs. 19, 20.
[2] Ulrich, op. cit., p. 295, pl. xxxviii, figs. 1–5.
[3] Jones, *Ann. Mag. Nat. Hist.*, 1885, ser. v, vol. xvii, p. 403.
[4] Miller, Cincinnati Quart. Journ. Sci., 1874, vol. i, p. 234, fig. 27.

obsolescence of the accessory lobe, and in the division of the posterior lobe, but the division is not so complete in *B. Chambersi*, nor the posterior horn so long and pointed and recurved. The complete division of the posterior lobe is more like that in the *B. tuberculata* group, but the lobes are connected ventrally. The posterior lobe is divided in *B.* (*Cer.*) *quadrifida*, Jones,[1] and there is a somewhat similarly situated accessory lobe.

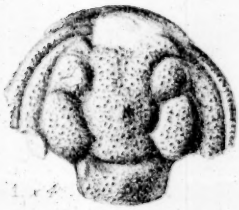
BEYRICHIA (CTENOBOLBINA?) SUPERCILIATA, sp. nov. Pl. XVII, Figs. 14, 14*a*.

Carapace small, semi-elliptical, about twice as long as wide, with rounded sub-truncate ends, sub-rectangular cardinal angles and hinge-line somewhat shorter than maximum length of carapace; anterior and posterior ends of sub-equal size. Valves rather convex, crossed by three lobes of unequal size and development, with a fourth smaller accessory one on inner side of posterior lobe; all lobes united below and merging into rounded sub-marginal ridge. Anterior, posterior, and ventral margins thick, with narrow flange projecting above the border and bearing a row of delicate radiating short straight spines set at equal distances apart; border thickened, inclined at right angles to plane of valves and widening somewhat posteriorly. Anterior lobe on valves broad, somewhat swollen, rounded, in width equal to about one-third the length of the valve; first sulcus nearly vertical, at right angles to cardinal edge and extending about one-half to two-thirds of the distance across valve; second lobe narrower than anterior one, sub-median in position, more prominent near dorsal edge, slightly curved back ventrally; second sulcus sub-parallel to first, of sub-equal length, a little wider dorsally and slightly curved back ventrally below accessory lobe; posterior lobe as large (or nearly so) as anterior one, with small accessory tubercular lobe about half-way up its inner slope, elongated and nearly vertical and almost circumscribed by furrows; accessory furrow short, connected above with second sulcus. Surface of valves minutely granulated, and dotted with a few small scattered tubercles which are especially numerous and have a roughly concentric arrangement near ventral margin; a specially large tubercle is situated close to the cardinal edge on each of the three main lobes and usually two near the ventral margin; three smaller ones are usually present in a vertical line on the middle lobe.

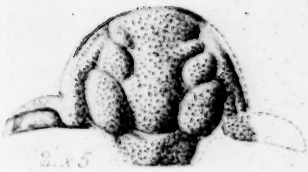
		mm.
Dimensions.	Length . .	about 2·25
	Width . .	about 1·50

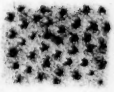
Remarks.—This species closely agrees with *B. ciliata*, Emmons,[2] but the presence of the small accessory lobe, the narrower posterior lobe, and the situation of the spines on the flange instead of along the edge of the valves sufficiently distinguish it. In the *B.* (*Ct.*) *subcrassa* section of the genus or sub-genus *Ctenobolbina* there sometimes exists, according to Ulrich,[3] a similar small accessory lobe.

[1] Jones, *Contrib. Micro. Palæont. Canada*, 1891, pt. iii, p. 66, pl. xi, figs. 19*a*, *b*.
[2] Jones, Q.J.G.S., 1890, vol. xlvi, p. 19, pl. iii, figs. 12–15; pl. iv, figs. 16–18.
[3] Ulrich, Proc. U.S. Nat. Mus., 1908, vol. xxxv, p. 309.


1. x 4

3. x 4

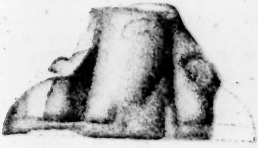

2. x 5


4a. x 12

4. x 2½

6. x 2½

5. x 12


7. x 2½

8. x 6

9. x 10

10. x 10

11. x 10

11a. x 10

13. x 10

13a. x 10

12. x 10

12a. x 10

14. x 10

14a. x 10

A. H. Searle del. et lith.

West, Newman imp.

New Crustacea from the Dufton Shales.

BEYRICHIA (TETRADELLA) TURNBULLI, sp. nov. Pl. XVII, Figs. 12, 12*a*, 13, 13*a*.

Carapace obliquely semi-elliptical, somewhat elongated with hinge-line as long as carapace and anterior end somewhat narrower than posterior, which is broadly rounded. Valves moderately convex, divided by three unequal sulci into four lobes, all connected ventrally with rounded sub-marginal ridge. Anterior lobe largest, more or less swollen and pear-shaped, in width equal to quite one-third the length of carapace, narrowing ventrally; first sulcus longest and widest, slightly oblique or curved back below, but starting at right angles to cardinal line, extending about two-thirds to three-fourths across the valve; middle lobe almost median, narrow, rounded, about one-half the width of anterior lobe, at right angles to cardinal edge; second sulcus sub-parallel to first, slightly oblique, of same strength as first; accessory lobe smallest of all, more or less nodular, not reaching cardinal edge, situated on inner side of posterior lobe, and connected by depressed narrow neck with sub-marginal ridge; accessory furrow short, weaker than others; posterior lobe rounded, about two-thirds the width of anterior lobe or nearly as large. Border of valves with horizontally extended rounded convex flange, separated off by deep marginal furrow; flange very narrow in front, widening posteriorly, crossed by regularly placed faint radial grooves, with fine striæ on edge, making a minutely fimbriated and denticulated margin. Anterior end of valves provided with a few small marginal spines set along the edge of border below the flange. Surface of valves minutely granulated, with an irregular concentric row of small sub-equal tubercles close inside marginal furrow, becoming a double row below anterior lobe and at front end; a few larger tubercles irregularly distributed on the lobes.

		mm.
Dimensions.	Length	about 3·00
	Width (across middle) . .	about 1·25

Remarks.—We may compare this species with *B.* (*Tetr.*) *marchica*, Krause,[1] and *B. subquadrans*, Ulrich,[2] but the lobation, character of the flange, and ornamentation of our species do not completely agree with either. In *B. complicata*, Salter,[3] the valves are shorter and wider, and the lobes are not developed relatively in the same manner; the surface also is smooth (except in the variety *decorata*), and the flange and ornamentation are distinct in character.

EXPLANATION OF PLATE XVII.

FIG. 1. *Acidaspis semievoluta*, sp. nov. Head-shield without free-cheeks. × 4.
,, 2. Ditto, ditto. × 5.
,, 3. Ditto. Imperfect pygidium. × 4.
,, 4. *Homalonotus ascriptus*, sp. nov. Head-shield without free-cheeks. × 2½.
,, 4*a*. Ornamentation of ditto. × 12.
,, 5. Ditto. Ornamentation of head-shield near anterior lateral angles of glabella. × 12.
,, 6. Ditto. Head-shield of young individual (?) without free-cheeks. × 2½.

[1] Krause, *Zeits. deutsch. geol. Ges.*, 1889, xli, p. 19, t. ii, figs. 9–11.
[2] Ulrich, op. cit., p. 306, pl. xxxix, figs. 1–3.
[3] Jones, *Ann. Mag. Nat. Hist.*, 1855, ser. II, vol. xvi, p. 163, pl. vi, figs. 1–5.

FIG. 7. *Homalonotus ascriptus*, sp. nov. Head-shield. × 2½.
,, 8. Ditto. Hypostome. × 8.
,, 9. *Beyrichia* (*Ceratopsis*) *duftonensis*, sp. nov. Left valve. × 10.
,, 10. Ditto. Right valve. × 10.
,, 11. Ditto, ditto. × 10.
,, 11*a*. Side-view of same. × 10.
,, 12. *Beyrichia* (*Tetradella*) *Tarnbulli*, sp. nov. Left valve. × 10.
,, 12*a*. Ditto, ditto. Impression of surface of same. × 10.
,, 13. Ditto, ditto. × 10.
,, 13*a*. Ditto, ditto. Impression of surface of same. × 10.
,, 14. *Beyrichia* (*Ctenobolbina*?) *superciliata*, sp. nov. Left valve. × 10.
,, 14*a*. Ditto, ditto. Impression of surface of same. × 10.

(*To be continued.*)

IV.—Petrology and Structure of the Pyritic Field of Huelva, Spain.

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(PLATE XVIII.)

Introduction.

THE great copper-mining district of Southern Spain and Portugal has been studied by several eminent geologists, and the problems presented in the geology of the field and of its ore-deposits have given rise to conflicting opinions. The three most debated points have been the origin of the ore-deposits, the relations of the igneous rocks, and the age of the sedimentary formations. The present paper, the field-work for which was carried out during the last summer season, deals in the main with the two latter points, and the writer takes this opportunity of expressing his indebtedness to Professor W. W. Watts and to Dr. C. G. Cullis for their advice and suggestions during the subsequent petrological studies at the Imperial College of Science and Technology, London.

General Relations of the District.

The copper-belt is situated at the southern end of the Iberian meseta, a fractured tableland whose essential rocks are of Palæozoic age. The meseta received its present structure with the tectonic movements and igneous eruptions of late Carboniferous and Permian times, and is one of the old Hercynian fragments, like the Armorican Mountains, the Central Plateau of France, the Vosges, and other districts of Europe. The axes of folding trend generally east and west, and the movements were accompanied by widespread intrusions of igneous rocks, and by the formation of many of the most important ore-deposits of the peninsula. The Hercynian disturbances were closed by extensive fracturing round the present edges of the tableland, notably along its south-east border. Thus the valley of the Guadalquivir follows the line of the insinking created at this period. This great fault cuts off the old mass across the strike of the folds, and is marked by a well-defined scarp along the edge of the valley between Seville and Cordoba. The fault-line appears to pass westward from the lower Guadalquivir, along the south coast by Huelva and the

mouth of the Guadiana, as far as the neighbourhood of Cape St. Vincent.[1]

Throughout Mesozoic times the area was comparatively undisturbed, but in the Eocene there commenced the great Tertiary disturbances of the Mediterranean zone, which raised the Betic Cordillera (Sierra Nevada and Serrania de Ronda) in the south-east and the Pyrenees in the north. Thus the structure of the peninsula was completed. The Tertiary earth-movements were accompanied by much igneous activity along the south-east coast, and also in the neighbourhood of Lisbon. Ore-deposition was again active during this epoch, but occurred chiefly along the Tertiary lines, the southern part of the meseta not being affected to any notable extent during these movements. Later Tertiary strata occupy detached areas which were basins of deposition in the old tableland, as well as much of the eastern and south-eastern districts. The insunken Guadalquivir trough, which connected the Mediterranean with the Atlantic transgression, has also been filled with Tertiary and later strata. Earth-tremors are still frequently felt along the old Tertiary lines, notably along the south-east coast and in the neighbourhood of Lisbon. The recent earthquakes generally also affect the line of weakness along the Guadalquivir Valley, past Cordoba, Peñaflor, Seville, and Huelva. Such was that which occurred on December 25, 1884.[2] Our knowledge of the structure of the peninsula is chiefly due to the researches of Macpherson, which are summarized in his latest paper.[3]

Outline of Geology.

The copper-field, which extends for a distance of 80 miles through the province of Huelva into Seville Province on the east and Alemtejo (Portugal) on the west, is composed of a belt of Palæozoic slates, fringed to the south by Tertiary and recent deposits, and succeeded on the north by pre-Cambrian schists and gneisses, and by less metamorphosed Cambrian strata. The Palæozoic rocks strike east and west, and have been thrown into a series of east and west folds. All the older formations are intruded by belts of igneous rocks which follow these same lines of direction, and were contemporaneous with the development of the structure of the district.

Metamorphic and Sedimentary Rocks.

The rocks which have been mapped as pre-Cambrian are found in a belt along the northern boundary of Huelva Province, outside the limits of the ore-bearing zone. They are chiefly gneisses, with bands of hornblende-schist and of crystalline and metamorphic limestones, succeeded by less altered schists and phyllites. Cambrian schists, with quartzites and greywackes, lie to the north of and are conformable

[1] E. Suess, *Das Antlitz der Erde*, English translation, Oxford, 1906, vol. ii, p. 124.

[2] Bol. Com. Map. Geol. Esp., Madrid, 1891, vol. xvii, pp. 241 et seqq. Salvador Calderon, "Movimientos pliocenicos y post-pliocenicos en el valle del Guadalquivir": An. Soc. Esp. Hist. Nat., Madrid, 1893, vol. xxii, p. 5. J. Gonzalo y Tarin, "Descripcion fisica, geologica, y minera de la provincia de Huelva": Mem. Com. Map. Geol. Esp., Madrid, 1886, vol. i, pp. 241–52.

[3] José Macpherson, "Ensayo de historia evolutiva de la peninsula iberica": An. Soc. Esp. Hist. Nat., 1902, vol. xxx, pp. 123–65.

with the upper members of the crystalline series, and are widely developed in the adjoining provinces of Badajoz and Cordoba. A belt of undoubted Silurian rocks, unconformable to the Cambrian, also occurs in the northern district. In these have been found graptolites, including *Monograptus Nilssoni* (Barr.), *M. latus* (McCoy), *M. linnæi* (Barr.), and *M. convolutus* (Hisinger),[1] as well as the so-called nereites,[2] identical with forms found in the French Pyrenees.[3]

In the slates of the mining belt to the south, similar nereites were found at Santo Domingo Mine in Portugal, at Lagunazo near Tharsis, and elsewhere. On this basis, on supposed lithological differences, and on the results of the researches of J. F. N. Delgado in Portugal,[4] a large area of the slates of the mineral zone was mapped as Silurian by the Spanish Survey. The rocks, however, contain no graptolites like those in the north, the lithological differences are insufficient to be of any value, and no unconformity can be detected between these rocks and the Carboniferous strata which compose the rest of the district. Further, since that date, the belief that the so-called nereites represent true fossils has been much discounted, and it is noteworthy that Delgado now places the nereite-bearing phyllites of Portugal in the Devonian.[5] Finally, the writer obtained a number of well-preserved specimens of *Posidonomya becheri*, the fossil found in the rocks of the district which are mapped as Carboniferous, in so-called Silurian rocks at the mine of Cabezas del Pasto, in Huelva, near the Portuguese border. All the evidence available, therefore, tends to show that the rocks throughout the mining district belong only to one period.

These rocks in general are quartz schists, phyllites, and thin-bedded slates, with bands of greywacke and quartzite, and, more rarely, limestones. A rapid alternation of greywackes and slates is frequently seen, as in the west of the province, at La Laja on the Guadiana, and in the Tharsis district. The strike of this sedimentary series is remarkably uniform throughout the field, approximating to W. 15° N. The rocks generally dip, at a varying angle, towards the north. They are fossiliferous at several localities round Rio Tinto, the slates near the Marismilla dam on the road to Nerva, and also adjoining the Bessemer plant, yielding good fossils. The following forms have been described by Lucas Mallada[6]: *Goniatites sphæricus, Posidonomya becheri, P. lateralis, P. gonzaloi, P. edmondia* (?), *P. constricta, P. barroisi*, and others. Several of these species, including

[1] Gonzalo y Tarin, loc. cit. sup., vol. i, p. 405.

[2] Ibid., p. 395.

[3] Ch. Barrois, "Sur les ardoises à néreites de Bourg d'Oueil (Hte.-Garonne)": Ann. Soc. Géol. du Nord, 1884, vol. xi, p. 219.

[4] J. F. N. Delgado, "Sobre a existencia do terreno siluriano no Baixo Alemtejo": Jorn. Sci. Math. Phys. e Nat., Lisbon, 1878, vol. v, pt. ii; and "Correspondance relative à la classification des schistes siluriens à néreites découverts dans le sud du Portugal": ibid., 1880, vol. vii, p. 103.

[5] J. F. N. Delgado, "Système silurique du Portugal": Commission du Service Géologique du Portugal, Lisbon, 1908, pp. 10 and 223. J. F. N. Delgado and P. Choffat, "La carte géologique du Portugal": Congrès Géol. Internat., sess. viii, 1900; Paris, 1901, p. 743.

[6] "Descripcion fisica, geologica, y minera de la provincia de Huelva": Mem. Com. Map. Geol. Esp., 1886, vol. i, p. 663.

chiefly *Posidonomya becheri*, were secured by the writer, as already mentioned, in slates near the lode of Cabezas del Pasto, in the west of the province. As regards the age of these rocks, Joaquin Gonzalo y Tarin, in his memoir on Huelva Province quoted above, places them in the Culm (Lower Carboniferous), while F. Römer[1] and R. Wimmer[2] both held the same view, and this is endorsed in recent work by F. Klockmann[3] and by Bruno Wetzig.[4] On the other hand, J. H. Collins states that Fraas and Etheridge both concluded the rocks around Rio Tinto to be of Devonian age.[5] The only rocks, however, mapped as Devonian by the Spanish Survey are some local occurrences in the provinces of Badajoz and Cordoba, north and west of the present district.[6] The bulk of the evidence, therefore, goes to support the conclusion that the rocks of the copper-belt of Huelva belong to the Culm, although the adjoining rocks in Portugal are now regarded by J. F. N. Delgado[7] as Devonian. In any case, there is nothing to show that they belong to more than one epoch, as has previously been emphasized by Klockmann[8] and by J. H. L. Vogt.[9] A small patch of Triassic limestones at Ayamonte in the south-west of the province, and a coastal belt of Tertiary and Quaternary strata, complete the geological column in this district.

Igneous Rocks.

These form an important series, not only as constituting a defined petrographic province, but also in the relation that their natural history bears to the origin of the lodes. They are distributed in belts parallel to the strike and to the axes of folding of the slates, and may be divided, for purposes of description, into three groups—the granites, the porphyries, and the basic group.

1. *Granites.*—These occur as a series of intrusive bosses in the older rocks in the north of the province, and as far south as the Concepcion Mine, and Campo Frio, near Rio Tinto, where they are intrusive into the Culm slates. On the whole, however, they are not developed in the mineral belt itself. They are evidently contemporaneous with the granitic rocks in other parts of the meseta, and form a part of the widespread series of plutonic intrusions accompanying the Hercynian earth-movements.

[1] "Über das vorkommen von Culm-schichten mit *Posidonomya becheri* auf dem Südabhange der Sierra Morena in der Provinz Huelva": Zeits. deutsch. geol. Ges., 1872, vol. xxiv, p. 589.

[2] "Die Kieslagerstätten des südlichen Spaniens und Portugals": Berg- u. Hüttenm. Zeit., 1883, vol. xlii, p. 327.

[3] "Ueber das auftreten und die entstehung der südspanischen Kieslagerstätten": Zeits. prakt. Geol., 1902, vol. x, p. 113.

[4] "Beiträge zur Kenntniss der Huelvaner Kieslagerstätten": ibid., 1906, vol. xiv, p. 173.

[5] J. H. Collins, "Geology of the Rio Tinto Mines": Quart. Journ. Geol. Soc., 1885, vol. xli, p. 246.

[6] Lucas Mallada, "Explicacion del mapa geologico de España": Mem. Com. Map. Geol. Esp., Madrid, 1898, vol. iii, p. 85.

[7] Loc. cit. sup.

[8] Loc. cit. sup.

[9] "Das Huelva-Kiesfeld in süd-Spanien und dem angrenzenden Theile von Portugal": Zeits. prakt. Geol., 1899, vol. vii, p. 241.

Petrologically, the most common type is a hornblende-granite, but the rocks vary from muscovite- and biotite-granites, through hornblende-granite and syenites, to granodiorites. Monzonite and tonalite also occur among them, considerable variation being shown in individual bosses.

2. *Porphyries.*—These rocks are very abundant both in the northern district of older rocks and in the mineral belt. In the former area they generally occur as marginal phases of the more deep-seated granite members, and also as later dykes intrusive into these. In the mining-field they frequently occur alongside the lodes, and owing to their profusion lodes are seldom found at a great distance from them.

The rocks show considerable variety, ranging, like the granitic rocks, from acid to intermediate types, with some alkaline phases. The most common type is probably a quartz-porphyry or rhyolite-porphyry, which is well developed at Rio Tinto (Pl. XVIII, Fig. 1). This rock contains abundant coarse phenocrysts of quartz, often corroded, and with inclusions of the felsitic ground-mass. The felspars are chiefly orthoclase and albite, but do not occur as phenocrysts in the more acid members. Subordinate muscovite and biotite are generally represented by chlorite and other alteration products. The ground-mass is felsitic or cryptocrystalline, and frequently contains abundant coarser grains of quartz. At times micropegmatites of quartz and albite occur, and the rocks become granophyric quartz-porphyries. With an increase in albite and microcline, quartz-keratophyres occur as local phases of the porphyries at Rio Tinto and elsewhere (Pl. XVIII, Fig. 2). A coarser-grained eurite, containing orthoclase and quartz, was observed near El Cerro, on the railway-line from Huelva to Zafra. Larger masses, such as occur in the neighbourhood of the Sotiel Mines, are typically granite-porphyries.

In the less acid members quartz phenocrysts disappear, the rocks as a rule are coarser, and include orthophyre or trachyte-porphyry, syenite-porphyry, and monzonite-porphyry. Such rocks occur north of the Tharsis Mine, at Sotiel, and elsewhere. Micrographic intergrowths are absent, and green hornblende is sometimes present, while the felspars are chiefly oligoclase and andesine.

As a rule the porphyries are found as sills and sheets, while the larger masses form bosses. In all cases, however, like the granites, they are disposed in belts parallel to the trend of the older sedimentary rocks. Owing partly to intense dynamic metamorphism of later date, contact effects are not well marked adjoining them, and mineralogical alteration of the slates can seldom be detected. The most usual evidences of intrusion are the presence of bands of porcellanite along the margins of the porphyries, and the occurrence of inclusions of baked slate.

Since their intrusion this series of rocks has been subjected to profound dynamic metamorphism. This is marked by straining and granulation of the quartzes, by crushing and complete sericitization of the felspars, and by the conversion of the ground-mass into an aggregate of quartz and finely divided sericite. Colourless epidote is often abundant as an alteration product of the felspars. Micropegmatites

show complete sericitization of felspar, leaving the quartz unaltered. Included portions of the ground-mass in quartz phenocrysts are also commonly preserved from the alteration which has affected the rest of the rock. Along the margins of the intrusions dynamic effects are particularly marked. Here the porphyries have frequently been converted to highly cleaved rocks with a greasy lustre. Under the microscope these show the same mineralogical changes as the more massive porphyries, carried to a greater extreme, while the effect of pressure has resulted in perfect schistosity, marked by folia of felted sericite (Fig. 3), which enclose granulated crystals of quartz and occasional aggregates of sericite and epidote representing altered felspars. As indicating the origin of these foliated types, it is significant that they correspond, in the nature of their phenocrysts, in each case with the adjoining massive porphyries. The coarser and more porphyritic rocks are accompanied by brecciated rather than foliated modifications, in which the crystals are arranged in a broken confused aggregate, which is, in the hand-specimen, with difficulty distinguishable from a pyroclastic rock. The absence of foreign constituents, however, and the remarkable uniformity of these cleaved and crushed types, as well as their microscopic structure and relations to the less altered porphyries, indicate that their present structure is the result of pressure and movement.

The age and relations of this series of rocks have been considerably discussed. Most of the geologists who have examined them, including J. H. Collins,[1] Gonzalo y Tarin,[2] L. de Launay,[3] and J. H. L. Vogt,[4] have regarded them as intrusive into the slates. The highly cleaved marginal phases were considered by Collins to be the result of pressure during solidification, by Tarin as effects of contact-metamorphism, and by Vogt as due to subsequent pressure and shearing. On the other hand, F. Klockmann has maintained, after considerable investigation, that the porphyries are subaqueous lava-flows contemporaneous with the deposition of the slates, and that the foliated and cleaved rocks associated with them are tuffs and ash-beds, which have been subsequently sheared.[5]

The present writer's conclusions, after the examination of a large series of exposures and of collected specimens from various parts of the district, are in agreement with those of Vogt and opposed to the views of Klockmann. The chief reasons for concluding that the porphyries are intrusive, and that the cleaved varieties are due to later pressure and movement, are as follows:—

(1) The occurrence of micrographic intergrowths and of corroded

[1] "Geology of the Rio Tinto Mines": Q.J.G.S., 1885, vol. xli, p. 245.

[2] "Descripcion fisica, geologica, y minera de la provincia de Huelva": Mem. Com. Map. Geol. Esp., Madrid, 1886, vol. i.

[3] "Mémoire sur l'industrie du cuivre dans la région d'Huelva": Ann. d. Mines, 1889, ser. VIII, vol. xvi, p. 407.

[4] "Das Huelva-Kiesfeld in süd-Spanien und dem angrenzenden Theile von Portugal": Zeits. prakt. Geol., 1899, vol. vii, p. 241.

[5] F. Klockmann, "Über die lagerartige Natur der Kiesvorkommen des südlichen Spaniens und Portugals": Sitzungsber. d. preuss. Akad. d. Wissensch., Berlin, 1894, vol. xlvi, p. 1173; and "Ueber das auftreten und die entstehung der süd-spanischen Kieslagerstätten": Zeits. prakt. Geol., 1902, vol. x, p. 113.

quartz phenocrysts with inclusions of ground-mass indicates hypabyssal rather than volcanic rocks.

(2) In a single exposure of porphyry the texture is frequently found to vary from coarse to fine in passing from the centre to the edge of the mass.

(3) Intrusion is indicated by porcellanous margins and by the presence of inclusions of slate, which have been caught up in the porphyries.

(4) In some cases an examination of the line of contact showed that it crossed the bedding of the slates, and that a later cleavage had been developed in the slates parallel to this line of contact.

(5) The occurrence of fine-grained porphyries as marginal phases of the granites in places is opposed to the view that they are lava-flows, as is also the occurrence of exactly similar porphyries in rocks of Silurian and Cambrian age in the north of the province.

(6) The close correspondence of the cleaved varieties with the associated massive porphyries in each case, the great uniformity of the cleaved types, and the absence in them of foreign constituents, all go to show that they are not of pyroclastic origin.

It is therefore concluded that the porphyries are intrusive into the slates, and that since their intrusion they have been affected by intense pressure, which has given rise to shearing along the lines of contact with the slates, which were naturally lines of weakness. To this shearing has been due the development of the cleaved and foliated varieties of porphyry. If this is the correct interpretation—and all the evidence gathered in the present work goes to show that it is—then the porphyries must, from their petrological analogy to and frequent association with the granitic rocks, belong to the same stage of igneous activity as these, but to a less deep-seated phase of consolidation. They were therefore intruded along with the plutonic masses during the disturbances of the Hercynian epoch. At the same time, the intrusions were probably spread over a considerable interval, as dykes of granophyre and felsite occur in places intrusive into the granites.

3. *Basic Intrusions.*—These have a similar distribution to the porphyries, but are less abundant. In the rocks of the mining field they occur generally as sills and occasionally as bosses. They include diabases, augite-porphyrites, dolerites, and augite-diorites. Augite is very abundant and generally ophitic in habit. The rocks have, as a rule, a high titanium content, marked by ilmenite, by pleochroic augite, and by abundant perovskite. The felspars vary from andesine to anorthite, brown hornblende is occasionally present, and olivine very rarely. The adjoining contact-altered slates show the development of, first, chlorite, and finally, abundant yellowish-brown epidote.

That this basic group, whose members appear from their generally close mineralogical resemblance to be all of the same age, is the youngest of the series of igneous rocks in the district, is indicated by the fact that they are found in places intrusive into both granites and porphyries, while they have been also intruded into the Triassic rocks at Ayamonte. Further, they are unaffected by the cleavage and

shearing seen in the porphyries, and the epidotization of the adjoining slates is subsequent to the sericitization of the slates which accompanied the development of cleavage throughout the area. The basic rocks must therefore have been intruded towards the end of the series of movements which has affected the district, and a considerable time-interval has clearly separated them from the older granites and porphyries.

Structure.

The slates of the area show a very uniform east-and-west strike, while the dip is generally to the north at a varying angle. This alignment is preserved in the associated igneous rocks. In the absence of folding or of overthrusting, there would be a very great thickness of rocks to account for between the coastal district and the northern metamorphic complex. In the absence of fossiliferous horizons, or of strata with a persistent lithological character, the structure of the district is difficult to unravel. The observed facts, however, suggest the presence of a series of inclined isoclinal folds, which have been followed, further, by overthrusting along the limbs of the folds, more especially in the neighbourhood of the junctions of porphyry and slate. These junctions have clearly in many cases been lines of movement, as indicated by the marginal phases of cleaved and brecciated porphyry. Further, the lode-zones also invariably occupy lines of structural weakness. Thus many lodes occur at the junction of slate and porphyry, some at the junction of slate and diabase, and the majority are contained in belts of crushed or sheared slate, enclosed between more resistent sills of porphyry or bands of greywacke or quartzite. The persistent lenticular form of the lodes also indicates that they occupy zones of fault-slipping. The shearing and faulting along the present lode-zones was, however, distinctly later than the folding of the rocks and the development of cleavage in them, since it involves the basic intrusions, and since breccias along the lode-walls, cemented by ore, are seen to contain fragments of previously cleaved and sericitized slate and porphyry. These thrust-movements, which preceded the deposition of the ores, were, therefore, the last of the series of Hercynian disturbances in the district.

Conclusions.

The general sequence of events in the area during the Hercynian epoch of crust-movement appears to have been as follows: The deposition of the Lower Carboniferous strata was succeeded by elevation and folding of the rocks, the forces acting along north and south lines, probably towards the north. With the inception of pressure came intrusions of granitic and porphyritic rocks, varying from acid to intermediate, throughout the stressed area. Further pressure after these intrusions resulted in cleavage of the slates and considerable dynamic alteration of the porphyries, especially along their margins, where they offered least resistance. After an interval of rest there was a renewal of sub-crustal forces, expressed first by the intrusion of basic rocks over the same area, and then by further pressure which resulted in shearing and probably overthrusting along zones of weakness. The deposition of the ores immediately followed these last

movements, the lodes being formed in the zones of sheared or shattered rock.

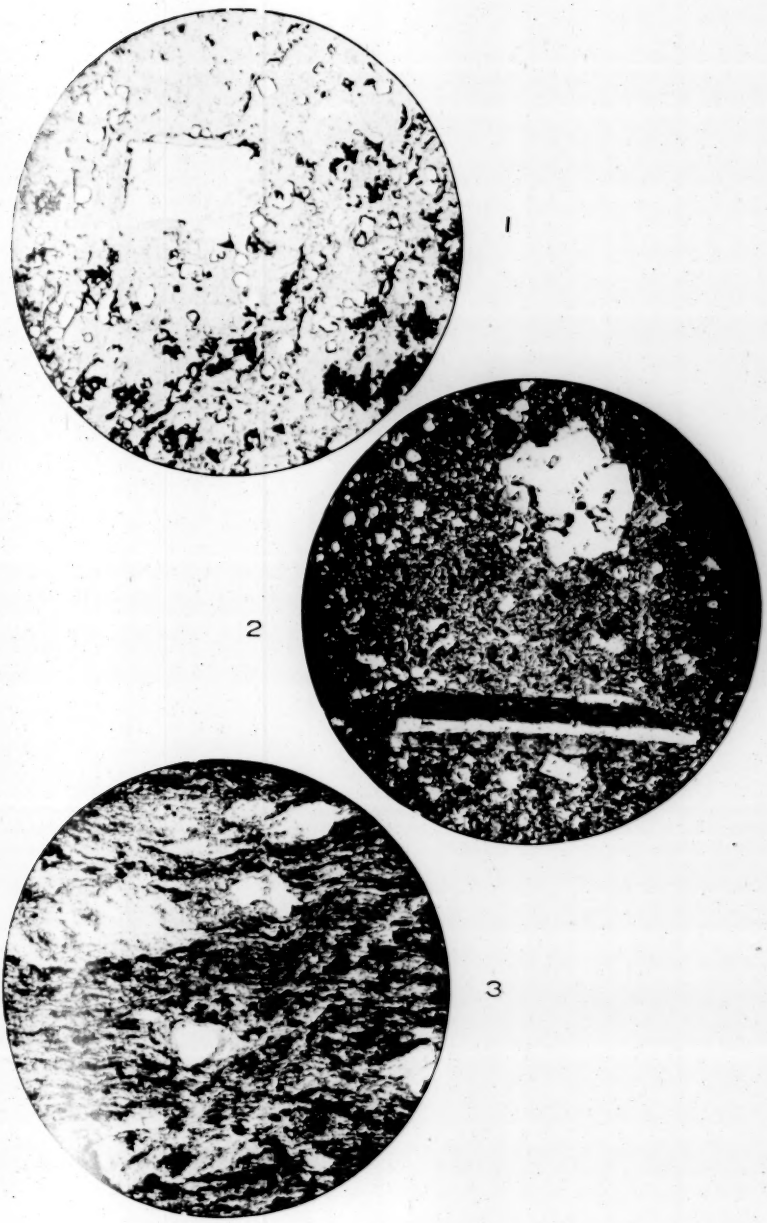
The district affords a good illustration of two features. In the first place, the development, by magmatic differentiation, of the series of igneous rocks has been closely connected with the earth-movements which have given the area its present structure. The igneous rocks and the tectonic structure are coextensive, and the magmatic differentiation has doubtless been attendant on the sub-crustal stresses of the Hercynian epoch. In the second place, the relation of the ore-deposits to the igneous rocks is, broadly speaking, a genetic one. The defined petrographic province, limited to a certain area, is accompanied by the equally defined group of pyritic ore-bodies, limited to practically the same area. In other words, there is here a metallogenetic province accompanied by a corresponding petrographic province. The association indicates the close dependence of ore-formation on earth-stresses and magmatic processes. While there is nothing to show that the lodes are genetically related to one particular group of igneous rocks, there is strong reason for believing that the concentration of the sulphides has been primarily a magmatic process, intimately bound up with the progressive differentiation which resulted in the igneous rocks now exposed. The ore-deposits, in short, represent the final product of the magmatic processes, just as the fault-zones in which the lodes occur were the last result of the earth-movements with which these magmatic processes were involved.

The Huelva copper-field is closely paralleled in almost every respect by the Avoca district in co. Wicklow.[1] Here a belt of Palæozoic slates is succeeded to the west by the Leinster granite massif, and the slates are intruded by a series of abundant sills and dykes of both acid and basic rocks, in part contemporaneous with and in part later than the granite. These intrusions have been intensely altered by subsequent pressure and movement,[2] and, as in the Huelva district, there is a general parallelism in the strike of the slates and in the alignment of both the granite and the abundant smaller intrusions. Finally, there occurs in the slates, and on the same general trend, a belt of pyritic lodes, sometimes enclosed in slate and sometimes adjoining sills of felsite or greenstone, but always in zones of shearing and crushing. Both structurally and mineralogically the ore-bodies of Avoca and those of Huelva show exactly the same features. Specimens of ore from the two fields are indistinguishable under the microscope. It is clear that in both districts similar agencies have been at work, with the production of exactly similar results.

EXPLANATION OF PLATE XVIII.

FIG. 1. *Rhyolite-porphyry*, Rio Tinto. The specimen contains quartz phenocrysts and abundant smaller grains of quartz, embedded in a felsitic or cryptocrystalline matrix, which has been largely converted to sericite. The rock is impregnated with pyrite and somewhat sheared. × 36.

[1] Explan. Sheets 138 and 139, Geol. Surv. Ireland, 1888.
[2] Sum. Prog. for 1900, Geol. Surv. Great Britain, p. 51.



Pyrites, Huelva, Spain: 1 Rio Tinto, 2 Tharsis, 3 Sotiel.

Fig. 2. *Trachyte-porphyry* (near keratophyre), Tharsis. Contains phenocrysts of orthoclase, albite, and corroded quartz. The ground-mass is a felt of very fine felspar laths with abundant coarser quartz grains. × 36.

Fig. 3. *Sheared porphyry*, Sotiel. Quartz phenocrysts have been crushed and granulated, felspars have been converted to aggregates of sericite fibres, and the ground-mass to a very fine felt of quartz and sericite, with a highly developed schistosity. × 36.

V.—Organic Remains in the Trias of Nottingham.

By H. H. Swinnerton, D.Sc., F.G.S., F.Z.S.

THE city of Nottingham is built upon the outcrop of the Trias. Building and road-making operations consequent upon its rapid growth often lead to the laying bare of the underlying Bunter, Keuper Waterstones and Marls. Unfortunately the work is usually carried on with such rapidity that good exposures are often missed. A temporary cessation of activities in one part of the Sherwood suburb, however, left a beautiful exposure of the Waterstones. A careful examination of this during the past few months has led to the discovery of footprints and fish-remains. The footprints are of a type which does not seem to fit into the generally used system of classification. In 1857 the Rev. A. Irving found a Cheirotheroid print in the railway cutting at Colwick. This is the only record of the previous discovery of footprints in this district.

Well-preserved remains of fish (*Semionotus*) are fairly common in one layer of light-coloured sandstone only 2½ inches thick. The upper surface of this is partly covered with small, ill-defined ripple-marks. The fish seem to have been left stranded upon this, and in their struggles to escape have made depressions and become buried in the sand they stirred up. The remains are buried in lenticular pieces of sandstone which can be lifted bodily out of the depressions. These vary in size from a few inches across to a couple of feet. The horizon at which they occur is evidently higher than that at which similar remains were found by Edward Wilson at Colwick in 1879.

The scales, fin-rays, and some bones are often perfectly preserved, but being embedded in sandstone they have to be dissected out with great care. As this is a tedious process, it seemed advisable to announce the find without delay.

REVIEWS.

The Coal Basin of Commentry in Central France.

THIS is the title of a paper by Mr. J. J. Stevenson (Ann. New York Acad. Sci., xix, p. 161, February, 1910). The basin was described in 1887 by Henri Fayol as about 9 kilometres long, 3 kilometres wide, and 700 metres deep; and it is isolated from two other small basins mainly by granite, the basins having been separated just prior to the time of the Coal-measures. Thus the deposits were always distinct, a conclusion formed by De Launay and

confirmed by Fayol. The most important contention of Fayol was that the coal-seams were formed, not in situ, but by transport; and to study this question Mr. Stevenson paid a special visit to examine the enormous excavations that have been made in mining the coal by stripping.

The Lower Coal-measures are formed almost wholly of rather coarse materials, with some unimportant lenticles of anthracite: the Middle Coal-measures consist chiefly of fine materials, and include the great coal-beds—mainly a single bed, the *Grande Couche*, 30 to 60 feet thick, but divided into two or more seams in a westerly direction: the Upper Coal-measures comprise more or less coarse detritus, and practically contain no coal.

The strata have a dip of about 30°, and this has been supposed to be the original slope of the beds. Fayol conceived that the strata were deposited in accordance with their specific gravity, the plant debris forming the beds of coal. Mr. Stevenson remarks that when one considers the enormous mass of the Grande Couche, not less than 30,000,000 cubic metres, it is difficult to realize that it could have been formed from such vegetable matter as could have been washed in from an area of about 26 square miles; and he maintains that the form and variations of the Grande Couche leave little room for doubt that the bed represents plants which grew where the coal now is. The marsh-vegetation consisted of *Cordaites* trees, with a dense growth of ferns, lepidodendra, and other plants; and the sandy clay underlying the Grande Couche, crowded with vegetable remains, is clayey enough to have prevented downward drainage.

Evidence is brought forward to show that the strata were exposed to tremendous pressure after consolidation. Occasionally the coal itself is crushed into small lenticles, which have been rubbed and polished. The author concludes that a differential subsidence, combined with the effect of compression and carbonization, would account for the high dips, which have been regarded as original.

Mr. Stevenson promises to publish a monograph on the formation of coal-beds. In the present communication he has not considered that the quiet, undisturbed condition of the organic remains, both plants and animals, so abundant in the coal-shales of Commentry, offered the best and most complete refutation of M. Henri Fayol's theory of the transportation and redeposition of the materials of these coal-beds in their present resting-place.

A reference to the great work by M. Chas. Brongniart on the wonderful insect fauna of Commentry would show how abundant and well preserved are the remains of these delicate and beautiful winged organisms.[1] Whilst in Europe and North America there have been described about 120 examples, at Commentry alone, since 1878, 1300 have been met with, of which the greater part is admirably preserved.[2]

After sixteen years of continuous labour, mostly devoted to the insect fauna of Commentry, M. Chas. Brongniart brought out his great work *Histoire des Insectes Fossiles des temps primaires* (Ste. Etienne,

[1] See GEOL. MAG., 1879, pp. 97–102, *Protophasma Dumasii*, Ch. Br.

[2] Ibid., 1885, pp. 481–91, Pl. XII, *Woodwardia*, *Caloneura*, *Corydaloides*, etc.

1893, 4to, pp. 496; and Atlas, 4to, pp. 44 and plates 53, many of which are double or folding).

"It has been reserved [says his reviewer[1]] to one favoured locality in a circumscribed area of Central France [Commentry] to furnish more specimens of fossil insects and in a better and more complete condition than in all the previously known localities of the world put together." It may be of interest to record here that Dr. Brongniart discovered at Commentry the largest Dragon-fly known (*Meganeura Monyi*), measuring 28 inches in the spread of its wings.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

March 9, 1910.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The President announced that the Council had awarded the Proceeds of the Daniel Pidgeon Fund for 1910 to Mr. Robert Boyle, B.Sc., who proposes to make a series of researches on the Carboniferous Building-stones of Scotland.

The following communication was read:—

"The Carboniferous Succession in Gower (Glamorganshire)." By Ernest Edward Leslie Dixon, B.Sc., F.G.S., and Arthur Vaughan, B.A., D.Sc., F.G.S.

The succession in three districts in Gower is described, the districts being so situated that a comparison of their respective developments can be interpreted in the light of the fact that, during Avonian time, the nearest coast lay to the north, with a general east-and-west trend. With the description of the lithological sequence are included notes on some breccia-like limestones, characteristic of D, and on 'lagoon-phases' and the origin of radiolarian cherts. To the faunal lists are added notes on the D_2–D_3 phase of the *Dibunophyllum*-zone, which distinguishes Gower from the rest of the South-Western Province at present known, and on the correlation of that zone with the Upper Bernician of Northumberland. From the faunal sequence it is concluded that the zones Z, C, S, D_1, and D_2 (the K Zone is poorly exposed) are characterized by the same assemblages as in the Bristol area.

The lithological sequence shows (1) that over the whole area the depth of the Carboniferous sea underwent a complete cycle of intermittent change during Lower Avonian time, the initial deepening being followed by gradual shallowing up to the top of the lower part, C_1, of the *Syringothyris*-zone, which was deposited almost at sea-level; (2) that a similar cycle marked the ensuing period up to the top of the *Seminula*-zone; (3) that a similar but smaller cycle took place in the *Dibunophyllum*-zone, the latter actually reaching the surface; and (4) that a fourth cycle, commencing with a far-reaching physiographic change, characterized the *Posidonomya*-zone.

Further, a comparison of the sequences and thicknesses in the three

[1] Geol. Mag., 1895, pp. 233–6.

districts shows that, not only were the downward movements of the sea-bottom during the first two cycles greater in the south than in the north, but also that the axis on which the movement during the first cycle hinged was different in direction from the axis during the second cycle. The bearing of these movements on the question of the delimitation of the divisions of the Avonian is then discussed. They suggest that the base of the upper part, C_2, of the *Syringothyris*-zone should form the base of the Upper Avonian. On the other hand, the base of C_2 in at least two localities is closely connected, faunally, with the zones below, whereas the fauna of the main mass of C_2 passes into S_1 without appreciable change other than the introduction of *Lithostrotion*. It will, therefore, in all probability be decided that the break between the Lower and the Upper Avonian should be taken at a level within C rather than at the base of the *Seminula*-zone. For the present, however, this question must be deferred, since it concerns the whole extent of the formation in Belgium, the North of France, and the British Isles.

The paper concludes with notes on some of the corals and Brachiopods, including one new species of coral and two new species and a new variety of Brachiopod.

March 23, 1910.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The President referred in sympathetic terms to the recent decease, at the age of 98, of Prebendary William Henry Egerton, who had been a Fellow of the Society since 1832.

The following communication was read:—

"On *Palæoxyris* and other Allied Fossils from the Derbyshire and Nottinghamshire Coalfield." By Lewis Moysey, B.A., M.B., B.C., F.G.S.

After reviewing the bibliography of *Palæoxyris*, the author records the finding of twenty-two specimens from Shipley Clay-pit (Derbyshire), and over 130 from Digby Clay-pit (Nottinghamshire), also several isolated examples from other localities in the district.

He describes *P. helicteroides* (Morris), noting especially the presence of a 'beak', which had not hitherto been adequately described. He then describes *P. prendeli* (Lesquereux) from Shipley Clay-pit, again noticing the formation of the 'beak'. The discovery of *P. Johnsoni* (Kidston) from Digby is noted, and it is proposed that this fossil be removed into the genus *Vetacapsula*.

The author also describes a specimen of *V. Cooperi* (Mackie & Crocker) from Newthorpe Clay-pit (Nottinghamshire). He discusses the differences between this and other specimens, and Mackie's type-specimen, but considers it unadvisable to multiply species.

A review of the bibliography of *Fayolia* is followed by the description of a new species from Shipley Clay-pit; also a small compressed example is described as near to *F. dentata* (Renault & Zeiller). The author then discusses the distribution of these organisms in time, and their possible affinities with the egg-capsules of the Cestracionts and the Chimæroids.

II.—Mineralogical Society.

March 15, 1910.—Professor W. J. Lewis, F.R.S., in the Chair.

G. W. Grabham: A new form of Petrological Microscope, with notes on the illumination of microscopic objects. The new instrument, which is of the 'Dick' or 'English' pattern, has a focussing substage carrying a series of condensers mounted on a triple nose-piece, each capable of being inserted in the axis of the instrument. A new explanation was given of the 'Becke' or bright-line effect, especially applicable to parallel polarized light traversing mineral sections which meet along inclined junctions.—W. F. P. McLintock: On Datolite from the Lizard District. Datolite, which is associated with calcite, chalcopyrite, and natrolite (rare) in veins and geodes at the junction of the serpentine and hornblende schist, Parc Bean Cove, Mullion, Lizard District, Cornwall, occurs in crystals measuring up to 2 cm. along the *b* axis, and displayed fourteen forms, of which two were new. An analysis gave SiO_2 37·45, CaO 34·67, Fe_2O_3 and Al_2O_3 0·57, B_2O_3 21·87, H_2O 5·67; total 100·23.—Arthur Russell: Additional notes on the occurrence of Zoolites in Cornwall and Devon. The occurrence of heulandite, a mineral hitherto not recorded from Cornwall, at Carrick Du Mine, St. Ives, Cornwall, was described; also of chabazite and heulandite at the Ramsley Mine, South Tawton, Devon.—Dr. J. W. Evans: A modification of Stereographic Projection. Faces below the plane of projection are represented by the same points as parallel faces above it, upper faces being distinguished by a plus and lower faces by a minus sign.—Dr. J. W. Evans: Axes of Rotatory Symmetry. Coincidence is complete or codirectional when equivalent lines and their directions coincide, incomplete or contradirectional when equivalent lines coincide, but equivalent directions of uniterminal lines are opposed; in both cases it is colinear. If a minimum rotation of $\frac{2\pi}{n}$ result in codirectional, contradirectional, or colinear coincidence, the axis of rotation has codirectional, contradirectional, or colinear symmetry, with cyclic number n.—Professor H. L. Bowman exhibited models illustrating space-lattices and Sohncke's point-systems.

CORRESPONDENCE.

THE USE OF THE TERMS 'LATERITE' AND 'BAUXITE'.

Sir,—Mr. Scrivenor's further remarks on this subject in the March number of the Geological Magazine, replying to mine in the number for November last, bring into sharp relief some of the difficulties which he and others experience with regard to the recognition and use of 'laterite' as a scientific term. I for one am not unaware of these difficulties. Indeed, I perceive one or two which are in my opinion more serious than those mentioned by Mr. Scrivenor. At the same time, all these difficulties taken together are small compared with those which prevent us from adopting the use of the mineralogical term 'bauxite' as a rock name. Furthermore, surely the fact that some engineers—and, alas! some others—have abused the term laterite,

is not a sound reason why geologists should relinquish their use of it in a scientific sense, especially when, as I pointed out in my previous letter, such a use can be shown to be quite consistent with the original meaning of the term.

Mr. Scrivenor now admits the inaccuracy involved in the unrestricted use of the term laterite for ferruginous surface products. He seems not to be aware, however, that his proposal to extend the use of the term bauxite is equally objectionable. His only remedy for the abuse of the word laterite is a still further abuse of the word bauxite, a course of procedure in which I confess inability to see any wisdom at all, practical or otherwise. Unfortunately, the term bauxite has been so carelessly used by most writers, that there is some degree of plausibility in his suggestion.

Now I fully admit that bauxite is a mineralogical uncertainty; and that there may not be a definite mineral corresponding in composition to the formula $Al_2O_3\,2H_2O$, which has always been attributed to bauxite by mineralogists; but until this possible fact has been definitely established and accepted by mineralogists, it seems to me that bauxite must remain a mineralogical name which cannot be applied indiscriminately by scientific workers to lateritic weathering products.

Is Mr. Scrivenor aware of the fact that the use of the term bauxite in a petrographical sense, for a mixture of hydrated oxides and other substances, would invalidate its use as a simple mineral name? If so, dare he assert, in view of the proved existence of xanthosiderite ($Fe_2O_3\,2H_2O$), that its aluminium analogue, the bauxite of mineralogy, does not exist? If not, what name does he propose to give to the possible $Al_2O_3\,2H_2O$ of mineralogy?

If it be ultimately proved that the mineral bauxite ($Al_2O_3\,2H_2O$) does not exist, and that the material which has hitherto been regarded as such is really and always a mixture of gibbsite ($Al_2O_3\,3H_2O$) and diaspore ($Al_2O_3\,H_2O$), it will then be necessary for mineralogists to abandon bauxite as a simple mineral name; and in that event it will possibly be available for petrographical use. If on the other hand, as is more likely to be the case, mineralogists decide that there is a definite mineral corresponding in composition to the formula $Al_2O_3\,2H_2O$, then the name bauxite will unquestionably belong to this substance, and this alone, in scientific nomenclature; that is, if Mr. Scrivenor and others fail, as I hope they will, in their efforts to degrade the word bauxite completely. This issue would more than ever leave a large and important function for the word laterite as a petrographical term. It is this scientific necessity of making provision for $Al_2O_3\,2H_2O$, the bauxite of mineralogy, which makes Mr. Scrivenor's suggestion positively harmful, and puts an insuperable difficulty in the way of its adoption by geologists.

Anent the rather misleading statement by Mr. Scrivenor, that "in other countries the original definition [of laterite] has been abandoned", I can only repeat the fact that the authorities of the present generation who have gone seriously into the study of laterite are at one as regards the scientific meaning to be attached to the term. The French and German schools from their study of African

deposits, and most important of all the officials of the Geological Survey of India who have to deal with the type occurrences, are all agreed as to the desirability of retaining the use of the term 'laterite' in much the same sense as I have defined it. The only culprits appear to be those who have either ignored the drift of recent tendencies in this matter, or who have preferred to attach more importance to the vulgar than to the scientific use of the term.

In conclusion, I fail to see any good reason why both laterite and bauxite should not be regarded as very useful scientific terms, the former more particularly for petrographical, the latter for mineralogical purposes.

T. Crook.

Scientific Department, Imperial Institute, S.W.

Geology of Bodmin and St. Austell.—In our review of the Geological Survey Memoir on this district (Geol. Mag., February, p. 85) we called attention to the omission from certain portions of the work of the initials of the responsible author. We are informed by Mr. D. A. MacAlister that the contributions made by the several authors to the pages of the Memoir are as follows:—

Barrow, G.: pp. 12, 27–8, 29–31, 32, 40–4, 63–4, 73–6, 83–91, 119–20, 180–1.
Flett, J. S.: pp. 44–53, 56–61, 65–8, 76–9, 93–104, 117, 8.
MacAlister, D. A.: pp. 54–6, 61–3, 64–5, 72–3, 91–3, 105–9, 111, 7, 131–69, 170–6, 179, 181.
Ussher, W. A. E.: pp. 1–40, 44, 68–72, 80–3, 109–11, 120–30, 176–8, 179–80, 181.

OBITUARY.

CHARLES EDWARD FOX-STRANGWAYS, F.G.S.

Born February 13, 1844. Died March 5, 1910.

We have to deplore the death of Mr. C. Fox-Strangways at the age of 66. We give his name here as he wrote it, omitting the second initial.

He was born at Rewe, a village situated on the River Culm about 4½ miles north-east of Exeter. There his father, the Rev. Henry Fox-Strangways, a grandson of the first Earl of Ilchester, was Rector. Another relation, the Hon. William Thomas Horner Fox-Strangways, had become a member of the Geological Society in 1815, and had communicated papers to the Transactions of the Society on the geology of Russia, and of the neighbourhood of St. Petersburg in particular. He served on the Council of the Society in 1820–1, was elected a Fellow of the Royal Society in 1821, and eventually succeeded to the title as fourth Earl of Ilchester.

C. Fox-Strangways was educated at Eton, about the same time as his cousin, the late Sir Redvers Buller, and afterwards proceeded to the University of Göttingen, where among other subjects he studied mineralogy, chemistry, and physics. In 1866, when war was declared between Austria and Prussia, he assisted Sartorius von Waltershausen, the professor of geology and mineralogy, in burying his precious collection of minerals, so as to prevent it from falling into the hands of the belligerents. Soon after his return to England, Strangways

was appointed, July 20, 1867, an Assistant Geologist on the Geological Survey, under Murchison as Director-General and Ramsay as Director. He commenced field-work on the western borders of Yorkshire near Todmorden, and was occupied for a time in surveying portions of the neighbourhood of Ingleton. Thence he worked eastwards over part of the great Yorkshire coal-field and in the country around Harrogate, across the Vale of York to the Jurassic and Cretaceous rocks of the East Yorkshire moors and wolds, residing for some years at Scarborough. Apart from the memoirs relating to these areas, which he prepared in explanation of the geological survey maps, Mr. Strangways wrote an elaborate general memoir on the Jurassic Rocks of Yorkshire.

In 1889 he was transferred to the Midland counties, and took up residence at Leicester until the close of his official career in 1904. In 1901 he had been promoted to be District Geologist when the Geological Survey was reorganized under the Directorship of Dr. J. J. H. Teall; but his retirement at the age of 60 was rendered desirable by weakness of heart, which at that time began to impede his wonted activity in the field. While at Leicester Mr. Strangways surveyed in detail the Leicestershire coal-field and prepared an important memoir on the subject; but his field-work extended over a much larger area, as indicated in the appended list of official publications. He also did a great deal to stir up local interest in geology at Leicester, in furtherance of which he planned and conducted numerous field-excursions in the district, and in 1903 and 1904 to Scarborough and Whitby, reports of which were printed in the Transactions of the Leicester Literary and Philosophical Society.

Methodical and painstaking in all his work, his accuracy and the care he took in mastering the literature on all subjects he dealt with, kept him free from the domain of controversy. It is thus interesting to mention that Professor P. F. Kendall, in his important paper on "A System of Glacier-Lakes in the Cleveland Hills" (1902), refers to "a great lake in the Vale of Pickering, postulated upon very inconclusive grounds by Phillips and other writers, but demonstrated in a very clear and convincing manner by Mr. C. Fox-Strangways".[1]

Strangways married in 1868 Annie Maria, daughter of the late George Flory of Ipswich, and had no issue. In 1873 he was elected a Fellow of the Geological Society, and served as member of Council during the years 1905–8.

He was fond of travel and had journeyed to South Africa, Canada, and the United States, and in almost every country in Europe. Spitzbergen and Iceland were visited in 1899, with his nephew Mr. A. W. Searley, who took a series of instructive photographs, some of which were published in illustration of a paper printed by Mr. Strangways in 1900.[2]

His chief publications were the numerous memoirs dealing with the geology of the districts he had surveyed; and of two of these, the

[1] Quart. Journ. Geol. Soc., vol. lviii, p. 473.

[2] We are indebted to Mr. Searley for some particulars relating to the life of his uncle.

memoirs on Harrogate and on the country south of Scarborough, he had prepared new editions within the last six years. During the past year and up to the time of his death, caused by heart-failure, he had been steadily engaged on an exhaustive geological bibliography of Yorkshire, and had practically completed this work, after many visits to the British Museum and other libraries for the purpose of seeing and verifying each record.

A staunch friend, and a man of most amiable disposition, although exceedingly reserved, his loss will long be felt personally as well as scientifically, by all acquainted with him and his works.

List of Geological Survey Memoirs.

1873. The Geology of the Country North and East of Harrogate. 2nd ed., 1908.
1878. The Geology of the Yorkshire Coal Field. (Notes contributed to Memoir by A. H. Green.)
1879. The Geology of the Country between Bradford and Skipton. (With J. R. Dakyns and others.)
1880. The Geology of the Oolitic and Cretaceous Rocks South of Scarborough. 2nd ed., 1904.
1881. The Oolitic and Liassic Rocks to the North and West of Malton.
1882. The Geology of the Country between Whitby and Scarborough. (With G. Barrow.)
1884. The Geology of the Country North-East of York and South of Malton.
1885. The Geology of Bridlington Bay. (With J. R. Dakyns.)
The Geology of Eskdale, Rosedale, etc. (With C. Reid and G. Barrow.)
1886. The Geology of the Country between York and Hull. (With J. R. Dakyns and A. C. G. Cameron.)
The Geology of the Country around Driffield. (With J. R. Dakyns.)
The Geology of the Country around Northallerton and Thirsk. (With A. C. G. Cameron and G. Barrow.)
1890. The Geology of the Country around Ingleborough. (Notes contributed to Memoir by J. R. Dakyns, R. H. Tiddeman, W. Gunn, and A. Strahan.)
The Geology of Parts of North Lincolnshire and South Yorkshire. (Notes contributed to Memoir by W. A. E. Ussher.)
1892. The Jurassic Rocks of Britain: Yorkshire. 2 vols.
1900. The Geology of the Country between Atherstone and Charnwood Forest.
1903. The Geology of the Country near Leicester.
1905. The Geology of the Country between Derby, Burton-on-Trent, Ashby-de-la-Zouch, and Loughborough.
1906. The Water Supply from Underground Sources of the East Riding of Yorkshire.
1907. The Geology of the Leicestershire and South Derbyshire Coalfield.
1908. The Geology of the Southern Part of the Derbyshire and Nottinghamshire Coalfield. (Notes contributed to Memoir by W. Gibson and others.)
1909. The Geology of the Melton Mowbray District and South-East Nottinghamshire. (Notes contributed to Memoir by G. W. Lamplugh and others.)

In addition to the various 1 inch and 6 inch geological maps, Mr. Strangways prepared a number of Horizontal Sections across the Oolitic districts of East Yorkshire which were accompanied by brief explanatory pamphlets; and also one sheet of Vertical Sections of the Oolites from Filey to Cloughton.

List of Principal Unofficial Papers.

1885. "The Harrogate Wells, or the Mineral Waters of Harrogate geologically considered": Proc. Yorks. Geol. Soc., viii, p. 318.
1894. "Dr. Alex. Brown on *Solenopora*": Geol. Mag., p. 236.
"The Valleys of North-East Yorkshire and their Mode of Formation": Trans. Leicester Lit. and Phil. Soc., iii, p. 333.

1895. "Glacial Phenomena near York": Proc. Yorks. Geol. Soc., xiii, p. 15.
1897. "Geology of the London Extension of the Manchester, Sheffield, and Lincolnshire Railway."—Part I: Annesley to Rugby: GEOL. MAG., p. 49.
"Notes on the Stratigraphy of the Newer Rocks of the Netherseal Borings": Trans. Fed. Inst. M.E., xiii, p. 598.
"Notes on the Coast between Redcar and Scarborough": Proc. Yorks. Geol. Soc., xiii, p. 248.
1898. "Sections along the Lancashire, Derbyshire, and East Coast Railway between Lincoln and Chesterfield": Quart. Journ. Geol. Soc., liv, p. 157.
"Filey Bay and Brigg": Proc. Yorks. Geol. Soc., xiii, p. 338.
"Notes on the Coast Sections between Hayburn Wyke and Filey": ibid., p. 356.
1900. "Notes on Spitsbergen and Iceland": Trans. Leicester Lit. and Phil. Soc., v, p. 404.
1907. Article "Geology" in the Victoria History of the Counties of England, Leicester, vol. i.
"The Geology of North-East Yorkshire in relation to the Water Supply of the District": Trans. Brit. Assoc. Waterw. Engin., xi, p. 113.
Article "Geology" in "A Guide to Leicester and District": prepared for Brit. Assoc.
1908. "Notes on the Geology of Leicestershire": Rep. Brit. Assoc. for 1907, p. 503.

H. B. W.

ALEXANDER AGASSIZ,

FOR. MEMB. ROY. SOC.

BORN DECEMBER 17, 1835. DIED MARCH 28, 1910.

WE regret to record the death of this distinguished naturalist on March 28 at the age of 74, when returning from Europe to the United States on board the s.s. "Adriatic".

Born at Neuchâtel, Switzerland, December 17, 1835, son of the celebrated Professor Louis Agassiz,[1] he accompanied his father in 1846 to the United States, where the elder Agassiz had been appointed Professor of Zoology and Geology in the University of Cambridge, Massachusetts. Educated at Harvard, where he took his B.Sc. degree at the age of 22, and of which University in 1878 he was elected a Fellow, Alexander Agassiz served for a short time on the United States Geological Survey. Turning his attention shortly afterwards to mining, he speedily proved so successful that, having acquired property in the Lake Superior region, he rapidly amassed a very large fortune in copper-mines.

The possession of independent means early enabled him to devote his time and studies to natural history pursuits. At first he assisted his father as Curator of Comparative Zoology at Harvard, and after his father's death he acted as Curator for eleven years. As his wealth increased he became a great benefactor to this Museum, not only by purchasing books and specimens, but by gifts of money up to £100,000. Commencing with the study of marine ichthyology, he subsequently devoted himself to, and became one of the highest authorities on, the Echinodermata, so that, on the return of H.M.S. "Challenger", he was asked to undertake the report on the Echinoderms collected during the voyage.

But the work for which Alexander Agassiz will be chiefly

[1] See obituary of Professor L. Agassiz (1807–73), GEOL. MAG., 1874, pp. 47–8.

remembered was that which, during nearly forty years, he carried on at his own expense in connexion with oceanography. The United States Government, with the greatest liberality and consideration for the interests of science, allowed him from time to time the use of their surveying vessels, the Captains of which were instructed to place themselves virtually under the orders of Agassiz himself. The naturalist, aided by a staff selected and paid by himself, carried on soundings and dredgings in every part of the globe, special attention being devoted to the study of coral reefs. Beginning in 1877 with the study of the Gulf of Mexico, the Caribbean Sea, and the Atlantic coast of America, Agassiz continued his work in 1880 by investigating the surface fauna of the Gulf Stream. Besides working out the details derived from the study of collections made during these voyages, the results of which were published in connexion with the Harvard Museum of Comparative Zoology, Agassiz wrote a well-illustrated account of his work, *The Three Voyages of the "Blake"*, in two volumes.

In 1891 Agassiz transferred his attention to the western shores of the United States and Central America, investigating the seas around the Sandwich Islands, and paying special attention to the coral reefs there, between 1892 and 1894. His explorations were extended during 1895–6 to the Great Barrier Reef of Australia, and in 1897–8 to the Fiji Islands. In 1899 and 1900 he was able to undertake a cruise among the various groups of coral islands lying between San Francisco and Japan. In 1901–2 Agassiz commenced his study of the Indian Ocean, paying especial attention to the Maldive Islands and their surroundings; and, in order to complete the examination of portions of the Pacific that he had not already visited, he devoted the years 1904–5 to a cruise among the important island-groups of the eastern half of the Pacific Ocean.

The intervals between his several voyages were occupied by Agassiz in the study of his enormous collections and the preparation of memoirs dealing with the results obtained. These were issued, regardless of expense as to their illustration, in the publications of the Boston Society's Museum of Comparative Zoology. No fewer than thirty volumes of memoirs and fifty-three volumes of bulletins are devoted to the results obtained from the study of these collections by Agassiz and the various specialists who assisted him. His own favourite place of work was Paris, where rooms were always allotted to him in the Museum of Natural History, and he had the fullest access to scientific libraries.

Of the value and importance of the results of these voyages it is impossible to speak too highly. Perhaps the most striking of the conclusions arrived at by him are those relating to great movements which have taken place in the bed of the Pacific in comparatively recent geological times. This is evidenced by the numerous upraised coral reefs which, following Dana, he described; in many of these the limestone rock, now at elevations of 1000 feet and upwards, has been more or less completely converted into dolomite.

It is not necessary, in face of the above statement of facts, to add that Agassiz was a man of indomitable energy. He thought as little